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Revised Operations Plan for the Katmai Scientific Drilling Project

A. R. Sattler, D. A. Blankenship

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Falling Mountain is in the Distance.

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REVISED OPERATIONS PLAN FOR THE KATMAI SCIENTIFIC DRILLING PROJECT

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ABSTRACT

This document describes the operations, logistics, and permitting requirements for constructing three scientific core holes in the Valley of Ten Thousand Smokes in Katmai National Park, Alaska. Two of the core holes will be located close to Novarupta Dome near the center of the vent for the historic volcanic eruption of 1912. One core hole near the dome will be drilled vertically to approximately 4,000 ft. The other core hole will be deviated 30 degrees from the vertical hole and will reach a depth of approximately 3,300 ft. The third core hole will be remote from the dome site, will also be deviated 30 degrees, and will reach a depth of approximately 660 ft. The objectives of the proposed core holes are to determine the chemical and physical behavior of magma in its host rock during eruption and intrusion, to determine the source, mechanism, and conditions of metals transport, and to measure the current subsurface temperature distribution to test models for the cooling of igneous systems.

The well designs include conductor and surface casing strings, a string of intermediate casing, and a full blowout prevention system. The drilling and coring operations will occur over two summer seasons with a shutdown during the intervening winter. Because of the remoteness of the field site, the operation must be mobilized, supplied, and demobilized by helicopter and supported by a camp near the dome. Baseline data provided for the area include descriptions of the geology, geochemistry, hydrology, climatology, air quality, flora and fauna.

ABSTRACT (Concluded)

Environmental safeguards and operational safety will be emphasized. Environmental safeguards will include procedures for environmental preservation and plans for fluid management, spill prevention, monitoring, and site reclamation. Ensuring operational safety will include professional conduct standards, well control, helicopter safety, and emergency training. The project will be conducted in a manner that has negligible long-term impact on the environment.

The Interagency Coordinating Group (ICG) for Continental Scientific Drilling is responsible for the planning and funding of this project, as well as for accompanying scientific studies. The ICG consists of representatives from the U.S. Department of Energy/Office of Basic Energy Sciences (DOE/OBES), the U.S. Geological Survey, and the National Science Foundation. The drilling and coring will be principally funded through the DOE/OBES. The ICG has requested a permit from the National Park Services (NPS) to conduct the operation. The project will also require permitting by other federal agencies and the State of Alaska. The NPS is considering the ICG permit request through the National Environmental Policy Act (NEPA) process. The original version of this document was prepared in part to begin the NEPA process. This revised Operations Plan provides an updated project description that is required to complete the Environmental Impact Statement.

PREFACE TO THE REVISED OPERATIONS PLAN

The publication of the original Katmai Operations Plan was necessary to initiate the NEPA process. Since the original Operations Plan was published, engineering plans have been refined and the overall operations scenario has been altered. Also, additional changes have been based on reviews by permitting agencies, industry, and consultants, as well as the availability of additional baseline data. Therefore, this Revised Operations Plan for the Katmai Drilling Project is required for the successful completion of the Environmental Impact Statement.

ACKNOWLEDGMENTS

The Geoscience Drilling Office (GRDO) at Sandia National Laboratories which prepared the document gratefully acknowledges the following organizations for their review of the draft "Katmai Drilling Project Operations Plan": the Alaska Regional Office of the National Park Service (NPS) in Anchorage; the Katmai Park Office of the NPS in King Salmon, Alaska; the Water Resources Division of the NPS in Fort Collins and Denver, Colorado; the U.S. Bureau of Land Management in Anchorage, Alaska; the U.S. Environmental Protection Agency in Anchorage; the Division of Governmental Coordination of the State of Alaska; and various divisions in both the Alaska Department of Environmental Conservation and the Department of Natural Resources in Anchorage. The concerns expressed in these reviews are addressed in this document. The GRDO is grateful for the in-depth discussions with personnel from the U.S. Fish and Wildlife Service in King Salmon, the Department of Fish and Game of the State of Alaska in Anchorage and King Salmon, and the Alaska Department of Labor in Anchorage. Thanks are given to personnel from the Unocal Geothermal Division for comprehensive discussions on well safety and control. The U.S. Geological Survey (USGS) in Anchorage is gratefully acknowledged for their collaboration and for careful reviews of all project documents. The U.S. Geological Survey (USGS) in Menlo Park is greatfully acknowledged for discussions on hydrology and water chemistry. The chief scientist at the University of Alaska in Fairbanks, J.C. Eichelberger, is most gratefully acknowledged for discussions on volcanology, project rationale, and reviews of the text. The outstanding work of Creative Computer Services and Tech Reps Inc., both of Albuquerque, New Mexico, in preparation of the manuscript and the accompanying illustrations is gratefully acknowledged.

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ACRONYMS

ADEC	Alaska Division of Environmental Conservation
COE	U.S Army Core of Engineers
CPR	Cardiopulmonary Resusitation
DNR	State of Alaska Department of Natural Resources
DOE	U.S. Department of Energy
DOE/OBES	U.S. Department of Energy/Office of Basic Energy Sciences
DOI	U.S. Department of the Interior
EIS	Environmental Impact Statement
EMS	Emergency Medical Service
EPA	U.S Environmental Protection Agency
ES&H	Environmental, Safety and Health
GRDO	Geoscience Research Drilling Office
ICG	Interagency Coordinating Group
NAS	National Academy of Science
NEPA	National Environmental Policy Act
NOAA	National Oceanographic and Atmospheric Administration
NPS	National Parks Service
NSF	National Science Foundation
OSHA	State of Alaska Occupational Health and Safety Administration
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
SA	Safety Analysis
SAR	Safety Analysis Report
SCBA	Self-Contained Breathing Apparatus
SOP	Safe Operating Procedure
TCLP	Toxicity Charcteristic Leaching Procedure
USGS	U.S. Geological Survey
VFR	Visual Flight Regulations

1.0 INTRODUCTION

Volcanism is one of the processes by which the Earth continues to evolve. It is the process by which low-melting portions of the planet's interior are transported upward and added to the upper crust, surface, and in the case of volatile components, the atmosphere. By taking samples and measurements of the inside a simple, young volcano soon after its eruption, scientists can greatly improve understanding of magma behavior as it approaches the Earth's surface, and its effects in the surrounding rocks of the Earth's crust. Such an undertaking fulfills the purpose of the Continental Scientific Drilling Exploration Act (Public Law 100-441) that was passed by Congress in 1988 to "enhance fundamental understanding of the composition, structure, dynamics, and evolution of the continental crust. . ." This "Revised Operations Plan for the Katmani Scientific Drilling Project," in conjunction with the Katmai Science Plan, "Direct Observation of a Young Igneous System: A Science Plan for Research Drilling in Katmai National Park, Alaska" (Eichelberger et al., 1991, 1989; Simon et al., 1988), outlines and describes the core drilling and scientific research necessary to investigate active volcanic processes at Katmai, Alaska. Katmai is the site of the historic volcanic eruption of 1912. Primary objectives of the project are the following:

1. to test models of explosive eruptions by the three-dimensional investigation of a well-preserved volcanic vent and the ash-flow sheet it produced;

2. to investigate geochemical profiles of the deposits not yet degraded by weathering or alteration to determine the process in which metals contained in the magma were transported and concentrated by gases following the eruption; and

3. to identify the processes and speed of the cooling of igneous rock by the measurement and interpretation of temperature profiles within a simple system of known young age.

The volcanic processes in Katmai National Park are uniquely suited to achieve these objectives because the 1912 eruption was a single, well-described volcanic event in a simple, uniform geologic setting. Moreover, structures of the volcano have not been modified by the large-scale collapse that normally accompanies eruptions of this size. The proposed observations will provide the first view of early post-eruption conditions inside a major igneous system. The conclusion that Katmai is uniquely suited for such an investigation has been endorsed by the Panel on Volcanic Studies at Katmai of the National Academy of Science (NAS) (NAS, 1989).

This drilling project will extract core continuously using methods of diamond coring. The project will perform down-hole scientific measurements in three core holes located in and near the Novarupta vent at the head of the Valley of Ten Thousand Smokes. Two deep core holes are planned close to the lava dome in the center of the vent, as well as a shallow core hole approximately 3 mi (~5 km) from the dome (Figure 1-1). One hole near the dome at the vent will be drilled vertically down the throat of a volcano to approximately 4,000 ft (~1,200 m) deep to study intrusive equivalents of pyroclastic units, deep structure, and the

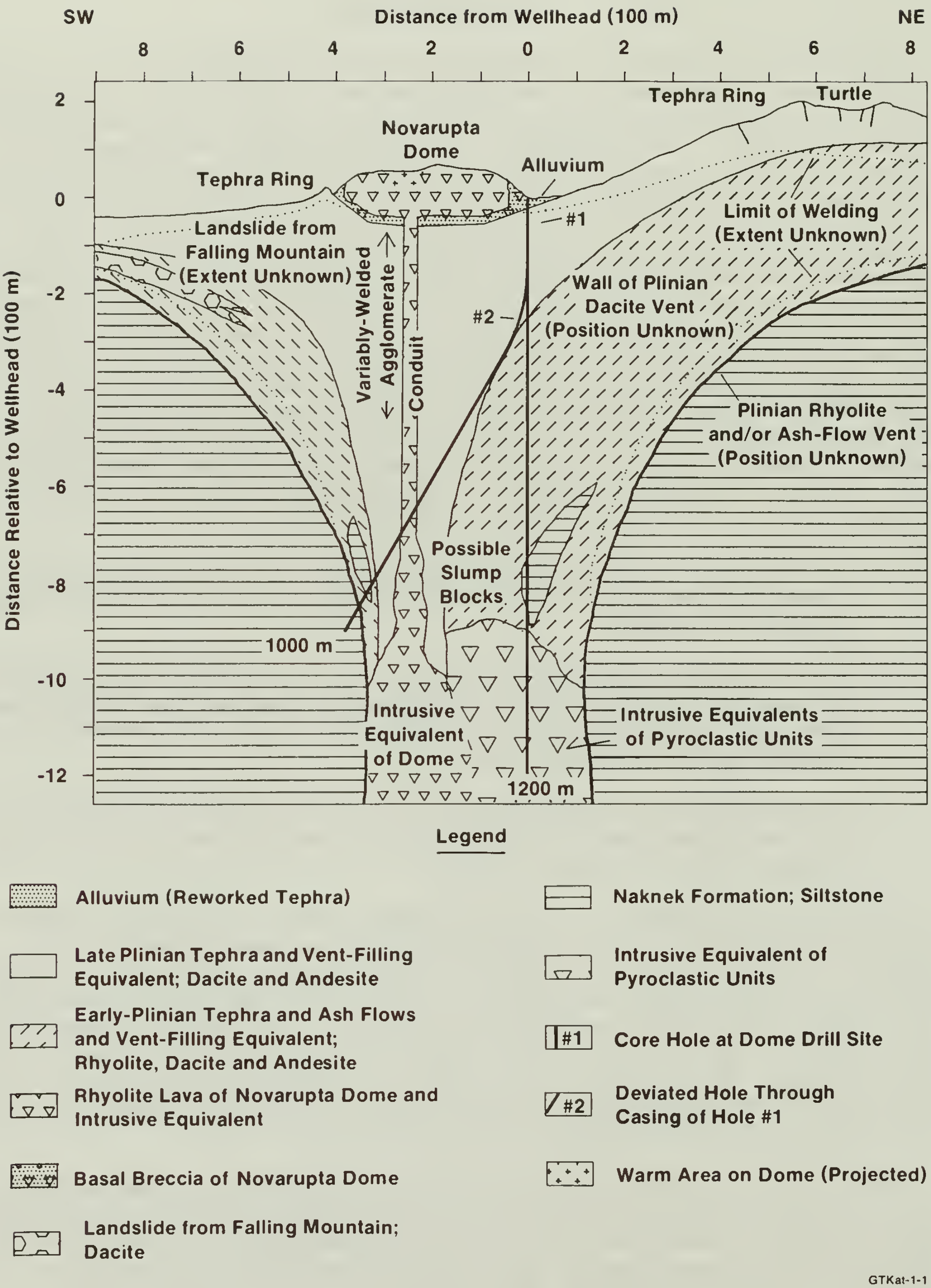

Figure 1-1. Illustration of the Geologic Objectives of the Proposed Core Holes. The schematic cross section of the vent shows the two wells at Novarupta Dome.

stratigraphy and temperature regimes of the vent. This vertical hole will be drilled to determine the characteristics of magma fragmentation during eruption and the speed that conduits cool. The other core hole at the vent, sidetracked off the vertical hole, will be approximately 3,300 ft (1,000 m) deep and will be drilled at a 60-degree angle from the surface under Novarupta Dome. The sidetracking core hole will be used to study the center-to-wall vent stratigraphy of the conduit, vent conditions, and the deep vent wall, to obtain a measurement of the vent diameter, and to determine the process of vent formation. The third core hole will be drilled remote from the dome site at a 60-degree angle from the surface to approximately 660 ft (200 m) to study a complete ash-flow sheet section and fissure fumarolic deposits. These studies will be performed to fully understand the history of the eruptions and determine the process of metal transport.

This project is proposed by a group of university researchers, national laboratories, and the U.S. Geological Survey (USGS) who conducted an integrated geologic and geophysics program in the Valley of Ten Thousand Smokes, Katmai National Park, Alaska (Figures 1-2 and 1-3). The surface-based geologic and geophysical portions of this program are largely complete and data have been published (American Geophysical Union, 1991). This group is sponsored and funded by agencies of the Interagency Coordinating Group for Continental Scientific Drilling (ICG), consisting of the U.S. Department of Energy/Office of Basic Energy Sciences (DOE/OBES), the USGS, and the National Science Foundation (NSF).

A description of the scientific investigations that will use the holes and the core obtained from them is presented in the Katmai Science Plan. The Science Plan has been presented to and accepted by the DOE, NSF, and the USGS. The drilling phase is described in this Operation Plan. A summary of the proposed core hole objectives is provided in Table 1-1.

The motivation for this project is a basic scientific interest in the behavior of the planet. Results from the scientific research at the Katmai site will find application evaluating the hazards of explosive volcanoes and can be applied elsewhere in finding and utilizing ore deposits and geothermal energy.

Ultimate responsibility for funding the project lies with the ICG and its constituent agencies. The ICG is a consortium of federal agencies that manage the U.S. Continental Scientific Drilling Program.

The USGS Branch of Igneous and Geothermal Processes will provide liaison between the National Parks Service (NPS) and the organizations that will be conducting operations at Katmai. The USGS has full authority to execute NPS orders for the Katmai Drilling Project. The DOE will be the legal operator of drilling operations, and Sandia National Laboratories will act as their agent. Sandia National Laboratories will be responsible for managing the drilling, coring, and field operations and will accept directions from the NPS through the USGS liaison officer.

The ICG has chartered the Principal Investigators and the Geoscience Research Drilling Office (GRDO) at Sandia National Laboratories to begin detailed planning of the project and to ensure that the goals set by the Science

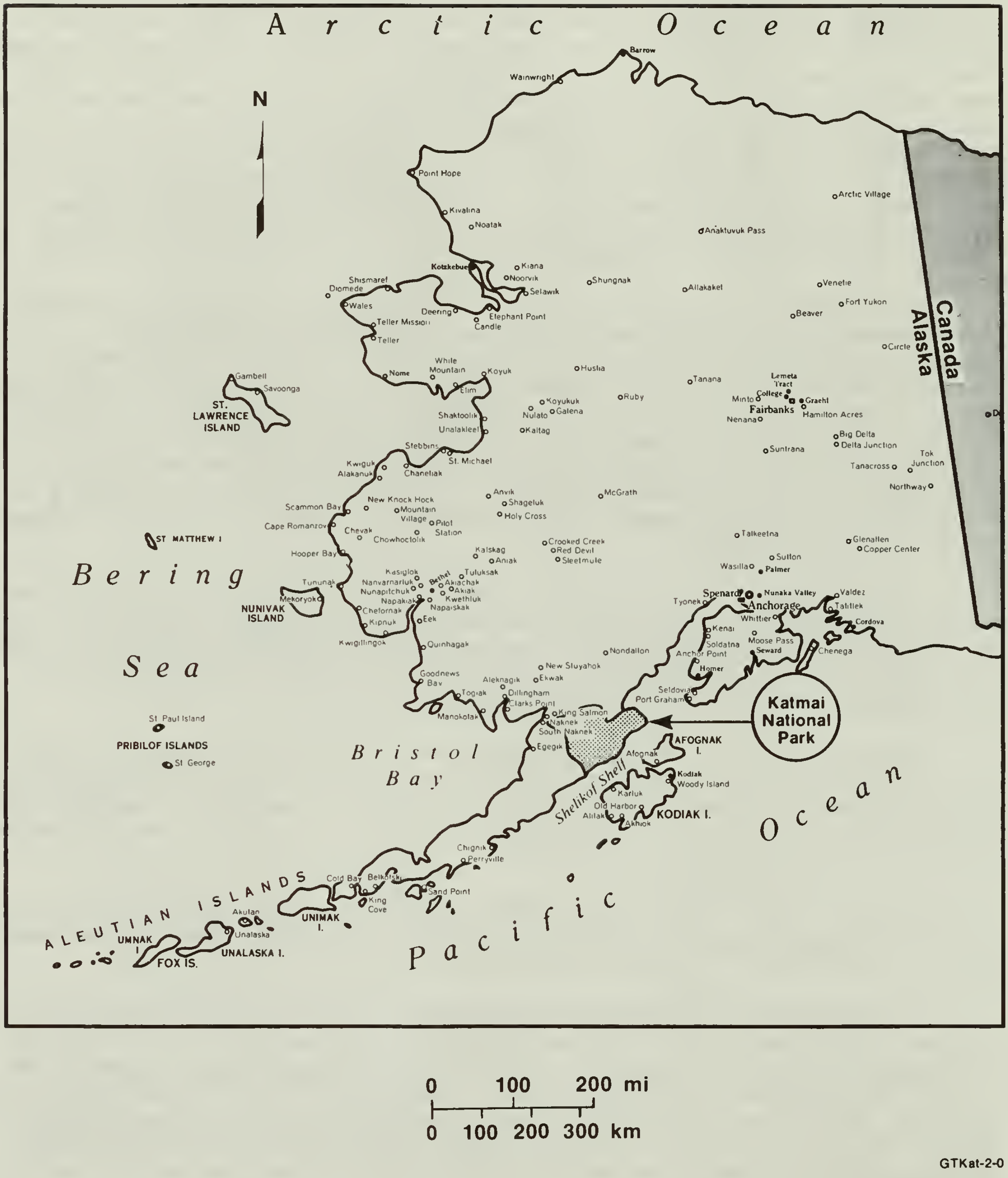

Figure 1-2. Map Including Katmai National Park; the Bristol Bay Area; Naknek, King Salmon; and the Anchorage Area

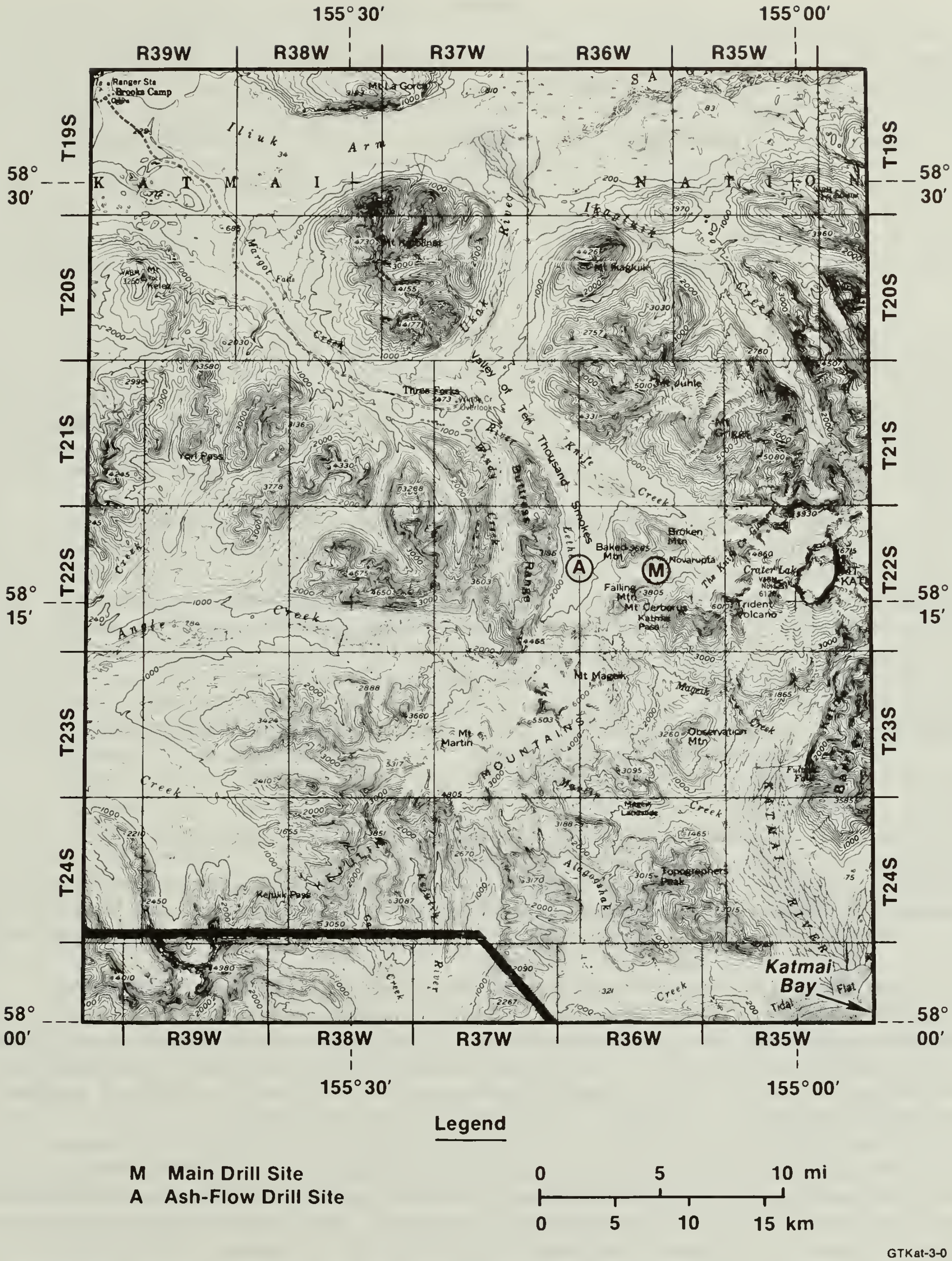

Figure 1-3. Map Showing the Location of Novarupta Dome Within Katmai National Park, Brooks Camp, the Valley of Ten Thousand Smokes, Katmai Pass, and Katmai Bay Tidal Flats on the Pacific Ocean

Table 1-1

Summary of Proposed Core Holes

Hole	Location	Depth	Dip From Horizontal
1	Center of Vent	1,200 m	90°
2	Center of Vent	1,000 m	60°
3	5 km from Vent	200 m	60°

	Objectives	Basis for Siting
Hole 1	Intrusive Equivalents of Pyroclastic Units Deep Structure and Stratigraphy Highest Temperature Regime	Surface Geophysics of Novarupta Dome
Hole 2	Novarupta Conduit Center to Wall Vent Stratigraphy Vent Conditions Deep Vent Wall	Positioned structure of Novarupta Dome
Hole 3	Section of Ash-Flow Sheet Section at Middistance Sampling Fissure Fumarolic Deposits	Distance from Vent Distribution of Fumarolic Deposits

Plan are developed into a well-planned and well-executed engineering operation. The GRDO was previously established to implement the portions of the U.S. Continental Scientific Drilling Program that are funded by the DOE/OBES.

The Katmai Drilling Project will be a significant logistical effort operating within stringent safety and environmental constraints. Due to the remoteness of the site, the operation will be supported by helicopter flights, a drill site, and a camp. The equipment for this project could be mobilized and barged from the Seattle and Anchorage areas. A smaller diamond coring system (rather than oil field drilling) will be utilized.

The site is environmentally sensitive because it is within both a national park and a wilderness area. However, other drilling operations have been successfully completed in sensitive areas, for example, in the thermal areas of Hawaii Volcanoes National Park (Colp and Okamura, 1978; Hardee et al., 1981) and in Yellowstone National Park (White et al., 1975). Because of the recent volcanism in the area, high temperatures may be encountered and current drilling technology will be exercised to the fullest extent. The NPS and the State of Alaska (among others) will monitor all phases of the

operation. Informal discussions with permitting agencies have been in progress for some time (Chapter 2.0). Some of these agencies have reviewed earlier versions of this Operations Plan (Sattler, 1990): the Alaska Regional Office of the National Park Service in Anchorage; the Katmai National Park Office of the NPS in King Salmon, Alaska; the Water Resources Division of the NPS in Fort Collins and Denver; the USGS in Anchorage and Menlo Park; the U.S. Bureau of Land Management in Anchorage; the U.S. Environmental Protection Agency (EPA) in Anchorage; the Division of Governmental Coordination of the State of Alaska; and various divisions in both the Alaska Department of Environmental Conservation (ADEC) and the Department of Natural Resources in Anchorage. Experts in industry have also received earlier versions of this document. Their input is also contained herein.

This Operations Plan provides a detailed description of the proposed operations that are essential to the successful commencement and completion of the project. Also, this document provides drilling information that could be submitted to permitting agencies. As a result of the permitting process and discussions with personnel from permitting agencies, minimal impact on the environment will be ensured.

One purpose of the original version of this document was to initiate the National Environment Policy Act (NEPA) and to show permitting agencies and other interested parties the scope of the project. This revised version of the document provides important source material that is required to prepare the Environmental Impact Statement (EIS). Further engineering analysis of the project and further reviews by permitting agencies since the November 1990 publication date of the earlier document necessitated several revisions. The engineering analysis included results from a park visit made in the summer of 1991 to obtain data for detailed site and waterline layouts.

Other supporting documents are the statement issued by the NAS discussing the uniqueness of the Katmai site among volcanic sites worldwide (NAS, 1989), and a letter of intent to the NPS from the ICG. (In addition to the review by the NAS, the Katmai Science Plan has been reviewed by (1) individual experts at the request of DOE, USGS and NSF, (2) the DOE/OBES Continental Scientific Drilling Program Review Group, (3) NSF-sponsored Science Advisory Committee, and (4) the ICG-appointed Katmai Science Experiments Panel.)

As part of the NEPA process, the NPS as Land Manager of Katmai National Park began a formal review and evaluation of the drilling project and is managing the preparation of the EIS. Thus the NPS is the Lead Agency in the NEPA process. The USGS is a Cooperating Agency. A notice of intent to prepare an EIS was published in the federal register on January 29, 1991. Public scoping meetings to identify issues of concern requiring careful environmental analysis in the EIS were held in Anchorage, Alaska, on April 15, 1992, and in King Salmon, Alaska, on April 16, 1992. The Draft EIS will be available in late 1992 or early 1993. The EIS is being funded by the constituent agencies of the ICG through the USGS.

Much of the content of this document is structured to conform to specific requirements from the NPS in accordance with Title 36, Part 9(B) of the U.S. Code of Federal Regulations (CFR). However, this document also discusses issues raised by other permitting agencies, such as various agencies of the

State of Alaska and the EPA. For example, the geothermal regulations of the State of Alaska provide a comprehensive set of detailed drilling rules for use in planning and conducting a prudent, safe operation with minimal impact to the environment (State of Alaska, 1986). Both the NPS and the State of Alaska share concern and permitting authority over all environmental aspects of the proposed operation.

The proposed management of the project is discussed in Chapter 2.0. Chapter 3.0 describes the permitting and compliance requirements in detail, along with approaches to solutions concerning legal issues. Chapter 4.0 provides a general description of the area, its geology, geochemistry, and hydrology with appropriate maps, drill site layouts, and camp layouts.

The core hole design and planned drilling operations are based on the geological site description provided in Chapter 5.0. The scientific goals and drilling objectives of the project are included in Chapter 6.0. Core hole designs and the drilling operations are described in detail in Chapters 7.0 and 8.0. These hole designs and drilling procedures were prepared, in part, with data from recent scoping that was performed jointly by the GRDO and consultants with industry. Chapter 8.0 discusses proposed drilling fluids, lost circulation, fluid management, and the advanced engineering that will be performed before fielding. A broad overview of major safety issues is provided in Chapter 9.0.

Chapter 10.0 describes the actual and potential hazards of the drilling project, as well as planned hazard mitigation, accident containment, and environmental protection. Means of preventing and mitigating potential problems if they occur are also included. A spill prevention and a containment plan concerning petroleum products, drilling fluids, and drilling fluid additives is provided.

Helicopter and camp operations to support the project are discussed in Chapter 11.0. Chapter 12.0 includes plans for field camp operations. Helicopter and camp operations have been planned to comply with environmental health, safety, and economic constraints. Transportation information has been gathered from detailed discussions with helicopter, camp, and barge companies operating in Alaska. The choice of helicopter routes was made after discussions with the helicopter companies based in Alaska, as well as with Alaska Fish and Game personnel and personnel from the U.S. Fish and Wildlife Service in King Salmon and Anchorage. Site support functions that will take place in King Salmon are discussed in Chapter 13.0. A site reclamation policy and plan are provided in Chapter 14.0. Benefits to the park as a result of the project are suggested. Steps for environmental protection are reiterated. Baseline data necessary to evaluate the impact of the operation, meteorology, climatology, air quality, fauna, and flora of the area are provided in Chapter 15.0.

The ICG agencies will conduct the project in accordance with professional and federal and state environmental and safety standards. The scientific goals of the Katmai Drilling Project must be attained in a manner that has a negligible long-term effect on the environment.

This document gives the scope and magnitude of Katmai Drilling Project operations. Plans were developed based on the experience of the GRDO at Sandia National Laboratories, experienced consultants, Alaska-based experts in the drilling industry, the permitting agencies, and industry personnel experienced in drilling and coring at high temperatures. Site layouts were carefully constructed by the GRDO. To assume, however, that no modifications of these layout will be necessary between the writing of this document and the 1994 fielding would be neither realistic nor practical. Drilling and camp contractors have not been hired; the government funding cycle precludes this until next year. (However no work will commence without the proper record of decision (ROD)). Nevertheless, these layouts represent a substantial refinement of the drawings in the earlier version of the Operations Plan and now provide sufficient detail to obtain a definite and realistic scope (footprint) of the proposed operation. Details of any subsequent changes to this plan will have little or no impact on the overall scope of the operation, but would continue to require NPS approval.

2.0 MANAGEMENT

The principal participants in the project are the ICG, the Principal Investigators (PIs), the GRDO at Sandia National Laboratories, the Curation Office at Los Alamos National Laboratories, and individual investigators from a variety of institutions. The ICG is a committee with representation from the three federal agencies that are major sponsors of the Continental Scientific Drilling Program: the DOE, USGS, and NSF. An Interagency Accord for Continental Scientific Drilling was reached among these sponsoring agencies constituting the ICG, which was formed to coordinate scientific drilling efforts within these agencies. The ICG constituency consists of academia, the USGS, and national laboratories, with occasional input from foreign scientists. The PIs of this drilling project are John C. Eichelberger of the University of Alaska, Fairbanks; Wes Hildreth of the USGS in Menlo Park, CA; and James J. Papike of the University of New Mexico. Thomas P. Miller and Christina Neal of the USGS Branch of Igneous and Geothermal Processes in Anchorage serve as liaison between the project and the NPS. USGS personnel act in many project capacities: as liaison between the NPS and the project, PIs, project sponsors through ICG, and project investigators.

The drilling and coring of the Katmai core holes will be funded principally through the DOE/OBES. The USGS and NSF will provide supplemental support for the scientific activities. The ultimate responsibility for the project lies with the ICG and its constituent agencies, although to implement the project, certain responsibilities will be delegated to the GRDO and USGS. The GRDO and USGS will be the principal field agencies and therefore the agents of the ICG.

The NPS will have ultimate and full authority over the conduct of the operation. The USGS will provide a liaison between the NPS and the Operator. Thus the NPS could exercise its authority to stop operations at any time, either directly or through the USGS. The DOE will be the Legal Operator with the Sandia National Laboratories GRDO as the agent. Thus the USGS will transmit all NPS directives to the GRDO for implementation, and the USGS will be accountable to the NPS for the implementation of those directives. The GRDO will secure all permits from appropriate state, federal, and local agencies. The DOE/Kirtland Area Office (DOE/KAO), as Legal Operator, will sign the permits and, through the GRDO, are singly accountable to these permitting agencies for the operation. Thus the GRDO is empowered by the DOE/KAO to respond to requests and directives from the permitting agencies. During field operations, the DOE/KAO will authorize the GRDO to have temporary authority to request amendments to the permits. The DOE also empowers the GRDO to assist the PIs and the USGS in interfacing with the public. The GRDO, as agent for the operator, will be in charge of all site operations, and, as site manager, make all field decisions related to these operations, will be responsible in case of an accident, and will lead in effecting remedial action.

In addition to the EIS mandated by the NPS, the DOE has its own NEPA requirements. The KAO, DOE/Albuquerque Operating Office (AL), and DOE/Headquarters (HQ) will collectively issue their own environmental decision document on the Katmai project. This decision document will be based on the draft EIS and other supporting documentation. The GRDO is responsible for

providing the DOE with necessary supporting documentation for the DOE environmental decision document. Figure 2-1 shows a block diagram of communication between the project and major permitting entities. Figure 2-2 shows a block diagram of the principal fielding agencies and principal contractors. Figure 2-3 shows a block diagram of environmental, safety and health (ES&H) aspects of Katmai, other than permitting.

The GRDO will have authority to make decisions in an emergency. A roster of all critical offsite technical and management personnel will be kept updated and available to all parties. Due to the remoteness of the site relative to the locations of sponsors and home laboratories of participants, it is essential that the Site Manager has authority to act on urgent decisions. If there is adequate time, the Site Manager will contact and involve additional authorized people in the decision-making process. Procedures for emergencies will be detailed in the site-specific Standard Operating Procedure (SOP).

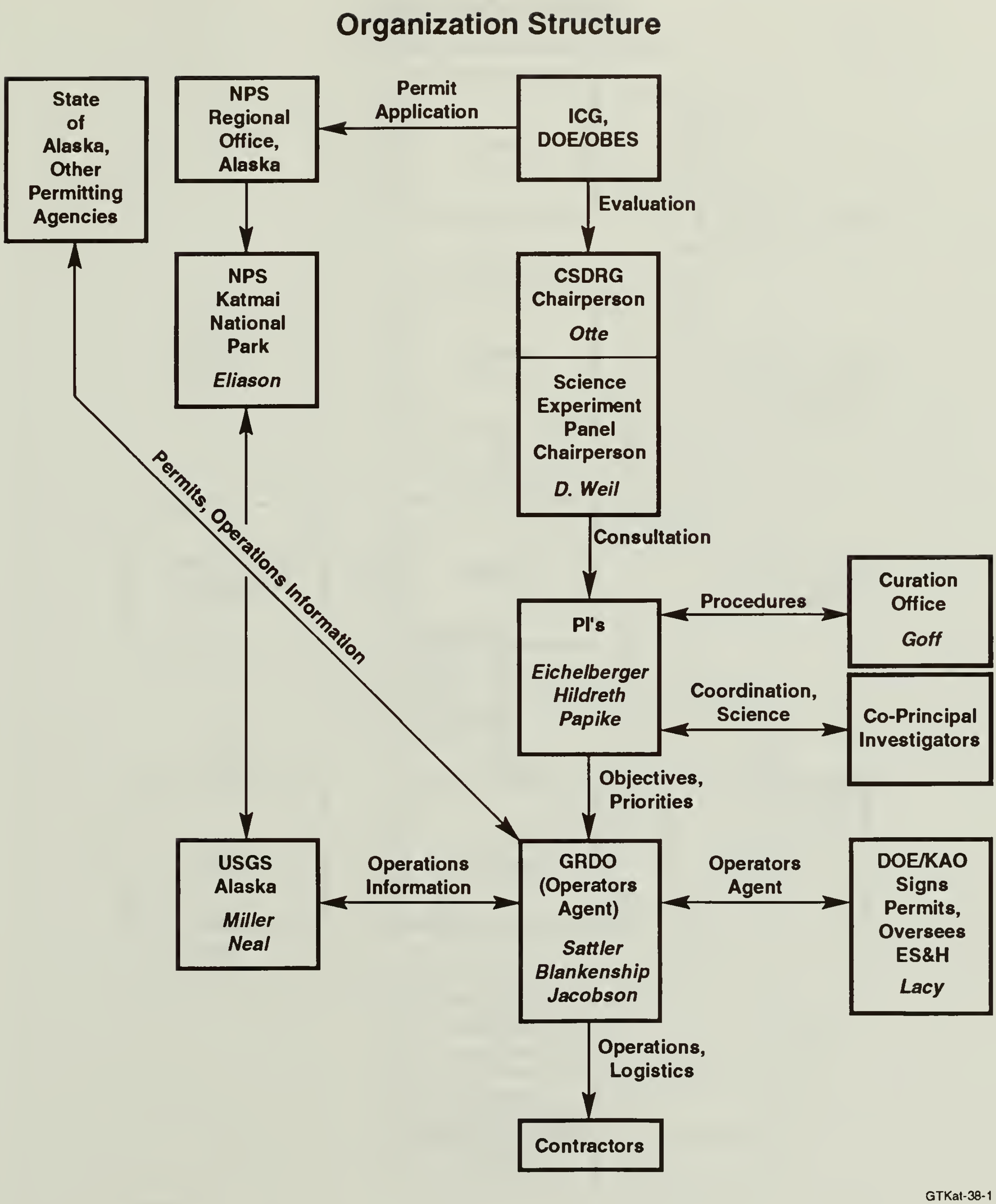

Figure 2-1. Diagram of Communications Among the Project and Permitting Agencies, the NPS, and the State of Alaska

Fielding Agencies

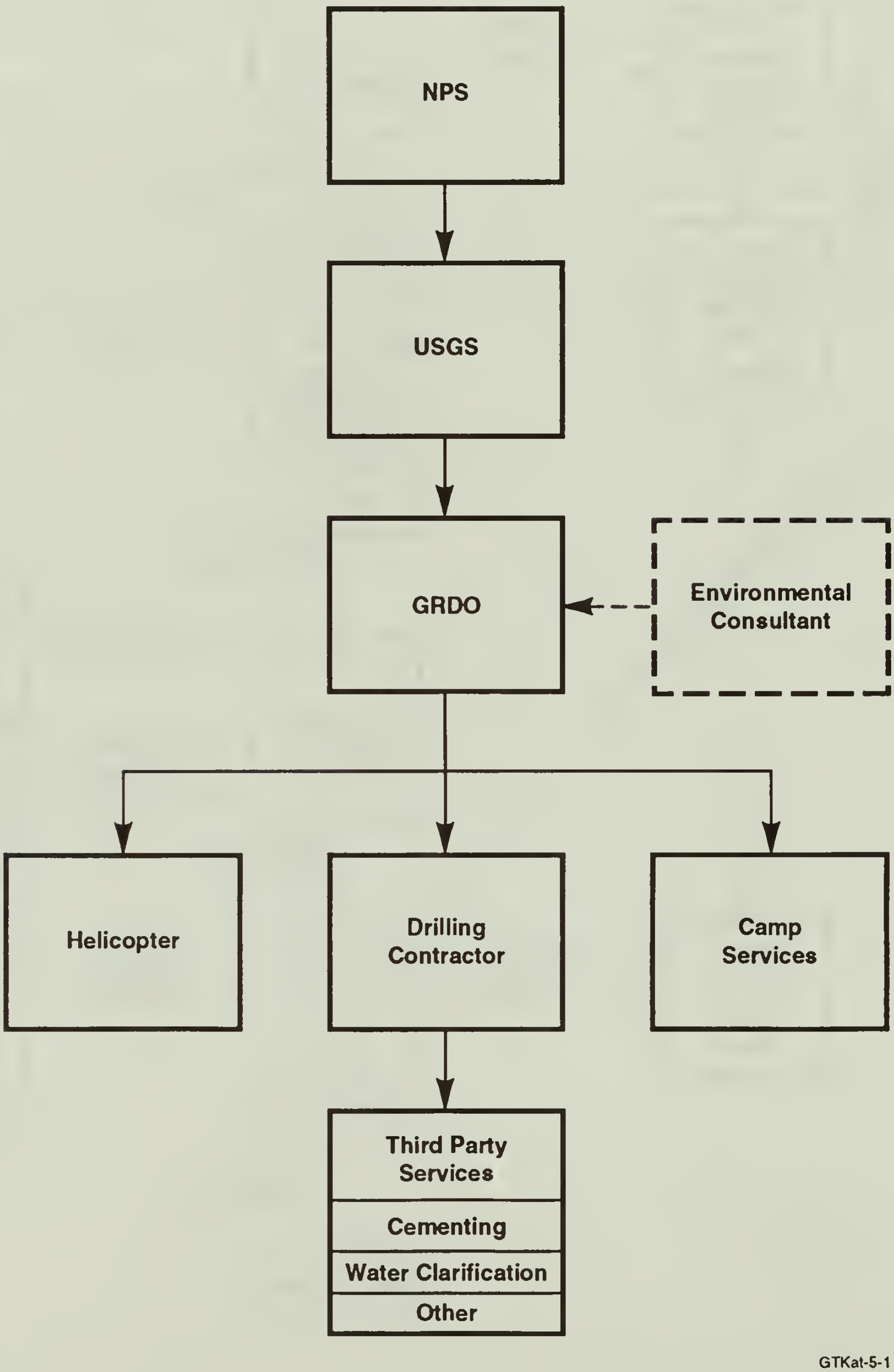

Figure 2-2. Diagram of the Principal Fielding Agencies and the Principal Contractors

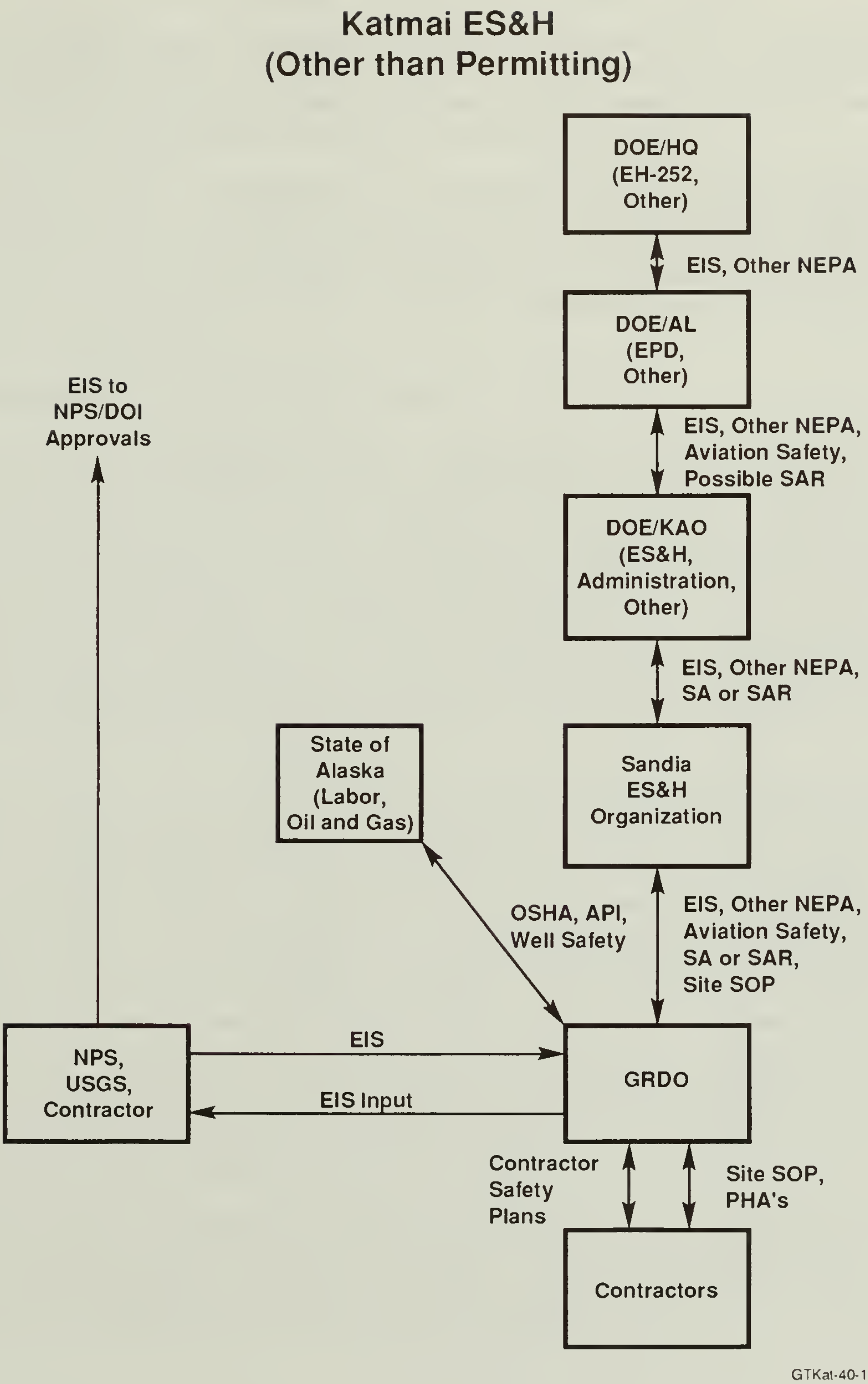

Figure 2-3 Diagram of Katmai Environmental, Safety and Health Other Than Permitting

3.0 PERMITTING COMPLIANCE AND LEGAL ISSUES

The ICG has formally requested a permit from the NPS to conduct the Katmai Drilling Project. The NPS has taken steps under the NEPA to consider the request. A Notice of Intent has been filed. Dames and Moore has been selected to assist the NPS and USGS in preparing the EIS.

Permits to drill and conduct the operation must be obtained not only from the NPS, but also from various agencies in the State of Alaska. Regulations from the EPA and the U.S. Army Core of Engineers (COE) are also applicable. Table 3-1 lists the formal permits thought to be required at this time. Table 3-2 lists the agencies for which less formal approvals and/or informal contacts are necessary.

3.1 Drilling Regulations and Permitting

The NPS required that information applicable to 36 CFR 9(B) will be provided through an Operations Plan. Information requirements for oil, gas, and other drilling activities are contained in 36 CFR 9(B). Largely, this Operations Plan centers on issues addressed in these regulations, such as ownership information, map data, area geology, operation description with timetable, reclamation policies, operating standards, natural resources, and environmental consequences. Information involving some of the latter categories will be expanded in the EIS. Other drilling requirements may be imposed through the NEPA process with the attendant EIS. The NPS Water Resources Division will act as a consultant to the NPS Alaska Regional Office and the Katmai National Park Office.

The Division of Oil and Gas of the Alaska Department of Natural Resources requires full permitting for the drilling of the Katmai core holes. These regulations govern geothermal drilling and are covered by directives in the Geothermal Regulations and Statutes, PDF 88-7, of the Alaska Department of Natural Resources (State of Alaska, 1986). These geothermal drilling regulations cover the administrative and technical issues of geothermal drilling. It has not been determined whether a formal permit filing will be necessary for the State of Alaska; however, they have been kept informed of the project and their earlier comments have resulted in changes to the plan. Moreover, the GRDO will write a letter to both the Oil and Gas Division and the Oil and Gas Commission, State of Alaska Department of Natural Resources, requesting collaboration, review of well control plans, and inspection of the blowout prevention system, etc. The NPS has given its assent to this collaboration in the interest of well safety.

Both the NPS and State of Alaska regulations confront critical issues such as core hole design, lost circulation, casing and cementing, well control and blowout prevention, logging requirements, and abandonment. These are discussed in subsequent sections of this document.

Table 3-1

List of Required Formal Katmai Permits and Approvals

Permit or Approval	Issuing Agency
Environmental Impact Statement (Favorable Record of Decision)	National Park Service, Alaska Regional Office, Anchorage
Operations Permit	National Park Service, Katmai National Park, King Salmon
Food Service Permit	Alaska Department of Environmental Conservation (ADEC), Environmental Health
Wastewater Onsite system	Alaska Department of Environmental Conservation, Environmental Quality
Wastewater Annular Injection (if required)	Alaska Department of Environmental Conservation, Environmental Quality
Air Quality Permit	Alaska Department of Environmental Conservation, Environmental Quality (may be required by law in 1994)
Well Drilling Permit	Alaska Department of Natural Resources (DNR), Oil and Gas Division
Water Use Permit	DNR, Land and Water Division
Solid Waste Acceptance at Bristol Bay Borough Landfill	Bristol Bay Borough (Informal approval given verbally)

3.2 Contacts With Federal Agencies Other Than the National Parks Service (NPS)

An oil spill prevention plan is required by the EPA under 40 CFR 112 and NPS under 39 CFR 9(B). Inventory information is required under 40 CFR 144.26. Informal contact has been made with the EPA at Region 10 Headquarters, Seattle, and at Anchorage. Drilling fluids and other wastes associated with drilling are excluded from the definition of hazardous waste under 40 CFR 261.4 of the Resource Conservation and Recovery Act (RCRA) but they continue to be strictly regulated by the RCRA Subtitle D program administered by the State of Alaska. Communication will be maintained with EPA and the state with respect to RCRA, the National Pollutant Discharge Elimination System, and groundwater under the Clean Water Act.

Table 3-2

List of Agencies With Which the Project Maintains Informal Contacts

Federal	
National Park Service, Water Resources Division, Denver and Fort Collins, Colorado	Reviews the Operations Plan and advises the Alaska Regional Office of the NPS on various aspects of the operation.
U.S. EPA, Seattle, Washington and Anchorage, Alaska	Informally advises project and is updated on project activities.
U.S. Army Corps of Engineers, Regulatory Branch, Anchorage, Alaska	Required a wetlands determination (and may require a permit to take the core).
U.S. Bureau of Land Management, Branch of Mineral Operations, Anchorage, Alaska	Informally advises project and is updated on project activities.
U.S. Fish and Wildlife Service, Ecological Services, Anchorage, Alaska	Follows EIS progress and advises NPS.
U.S. Fish and Wildlife Service, Alaska Peninsula/Becharof National Wildlife Refuge, King Salmon, Alaska	Informally advises project and is updated on project activities.
State of Alaska	
Alaska Division of Governmental Coordination, Anchorage, Alaska	Updated on project activities.
Alaska Department of Environmental Conservation, Division of Environmental Quality, Anchorage, Alaska	Informal discussions on air quality, RCRA concerns, and oil spills.
Alaska Department of Fish and Game, Habitat Division, Anchorage, Alaska	Informally advises project personnel and is updated on project activities.
Alaska Department of Fish and Game, Game Division, King Salmon, Alaska	Informally advises project personnel and is updated on project activities. Important advice is given in the selection of helicopter routes.
Alaska Department of Labor, Division of Labor Standards and Safety	Enforces compliance with Alaska/ federal OSHA standards and regulations. Discussions are under way.
Lake and Peninsula Borough	Has not identified requirements.

The COE has ruled that the area involved for the proposed drilling is not located in wetlands. Moreover, this project will not impact the ephemeral pond near the drill site, the River Lethe, or Knife Creek with discharge or fill material. (These are considered waters of the United States and, as such, are under the jurisdiction of the U.S. Army Corps of Engineers [COE].) This determination resulted from a letter from the GRDO to the COE providing data such as the location, elevation, geology, hydrology, and flora of the drill sites and surrounding area. Scientific nonhydrocarbon coring activities may require a permit from the COE.

The U.S. Fish and Wildlife Service, Ecological Services, is informed of the progress of the EIS. The U.S. Fish and Wildlife Service in King Salmon administering the Alaska Peninsula Becharof National Wildlife Refuge is also following the project because of the proximity of the refuge land to Katmai National Park.

The Bureau of Land Management has no formal permitting requirements, but has requested to be provided with all technical information.

3.3 Details of Surveillance Issues

The following issues will require surveillance by the NPS and the State of Alaska. (The NPS and the State of Alaska will share authority over the majority of these items because the NPS is concerned with the entire operation.)

- Water Use Water use will require a permit from the Water Management Section of the Alaska Department of Natural Resources. The state water use permit will be coordinated with the NPS Water Resources Section, Fort Collins, Colorado, before the formal filing.

- Air Quality The average emissions from all sites combined should be less than 1,100 kW combined (650 kW at the dome drill site, 200 kW at the ash-flow drill site, and 250 kW at the waterline pumps and heaters). If anticipated new regulations are put into effect in 1994, it will be necessary to request a permit.

  No open burning is planned. Burning will be performed with an incinerator. Concerns for waste incineration include optimal combustion of any burned material, proper training of any project personnel for conducting the combustion, and visibility of resulting smoke. A burn plan will be filed with the NPS and the state (Appendix A). A monitoring program will be in place to monitor for evidence of any hydrogen sulfide produced from this operation (Section 10.4, Appendix B).

- Noise Noise will be generated by the coring rig, diesel generators, and gasoline or diesel mud pumps. Noise abatement procedures may be requested by the NPS when the operation overlaps the main park visitor season. The noise generated by helicopter support will be of concern.

- Streams and Rivers Streams and rivers will be monitored for drilling fluids and drilling fluid products. (See Chapters 5.0, 8.0, and Appendix C.)

- Fuel Storage Diesel fuel, jet fuel for the helicopters, and other fuels will be stored onsite. Up to 95% of the fuel will be brought onsite during the main mobilization. The approximate fuel storage for the first operating season (see Chapter 8) will include 60,000 gal of diesel fuel, 4,000 gal of jet fuel, 200 gal of gasoline, and 16,000 gal of propane. Fuel storage in the second season will be approximately half of this. A contingency plan to mitigate spills is required by the NPS. The ADEC Division of Environmental Quality requires such a plan only if the amount of fuel involved is 10,000 bbl (420,000 gal) or more. A contingency plan is contained in this document, which will be on file with the Division of Environmental Quality. (The required EPA spill prevention plan outlined in 40 CFR 112 and the contingency plan for spills outlined in 18 AAC 75 are in Chapter 10.0 and Appendix D.)

- Hazardous Materials The only materials brought onsite that may be considered hazardous are drilling fluid additives in concentrated form. Drilling fluids as mixed and used in the formation will be nonhazardous. There is a very small chance that connate fluids or solids (cuttings) brought up during drilling could be toxic. Both the EPA and ADEC Division of Environmental Quality will be kept informed of the results of the sampling program.

- Drilling Fluids A fluid management plan is required by the ADEC Division of Environmental Quality for the storage of drilling fluids and drilling fluid additives and the handling of used drilling fluids. Fluid management is discussed in Chapter 8.0.

- Solid Waste Solid waste permits and evidence of arrangements with an approved landfill are required from the ADEC Division of Environmental Quality. Use of a trash compactor is planned at the site to facilitate transportation of nondrilling solids out of the park. Drilling waste must be placed in an area permitted for this material.

- Affected Animal Life The U.S. Fish and Wildlife Service and the Habitat Division of the Alaska Department of Fish and Game have at this time no formal requirements for the operation, although they may be called in by the NPS. The U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game wish to be informed of project proceedings and will work with the NPS in matters of joint concern. The project appears to be within the general (but not specific) use area of caribou, moose, and brown bears. Waterfoul should be minimally affected by the operation. Snow buntings nest around Novarupta Dome in the summer. Careful selection of helicopter routes can minimize the impact on mammals and waterfowl (see Chapter 15).

- Camp Various permits are required to operate a camp; e.g., a food service permit is required and a permit is required for a Class B or C

water supply. The camp must be constructed to standards set by the Alaska Department of Labor. Water testing will be performed to EPA specifications. A grey water leach field will require permitting by the ADEC Division of Environmental Health.

- Cultural Artifacts The DNR Office of History and Archaeology of the Division of Parks and Outdoor Recreation has deferred to the NPS and the NEPA permitting process for the preservation of cultural resources. The entire operation within the park will be on land surfaces formed in 1912, and no human habitation other than short-term visitor and scientific camps has occurred since 1912.

- Coastal Zone The Alaska Division of Governmental Coordination has notified the project that the activities centered at the proposed drill sites are outside of the coastal zone.

The GRDO contracted with an independent environmental contractor, CH2M Hill, to ensure all necessary permits are field correctly and to ensure compliance with all appropriate regulations and directives. They will make onsite inspections throughout the duration of the project to ensure compliance. The project contracted with MI Drilling Fluids Company to advise in issues related to drilling fluid additives.

3.4 Legal Issues

The DOE/KAO is the operator for the project. The GRDO at Sandia National Laboratories has been designated by the operator to carry out all field activities on behalf of the operator under a contractual agreement with the DOE.

The operator through the GRDO will be held responsible for the Katmai Drilling Project's compliance with existing statutes and regulations concerning the actual drilling, coring, logging, monitoring, and associated logistical support operations. The operator will be responsible for all project activities regarding the protection of the environment and compliance with safety laws, regulations, and professional standards.

The DOE and the Department of the Interior (DOI) are responsible for all principals in the field. Ultimately, the U.S. government indemnifies and holds each of its operating agencies harmless against any delay, failure, loss, expense, or damage of any kind in accordance with existing operating agreements. Through contractual or accepted operating agreements between the project fielding agencies and their sponsors, the financial responsibility for the project rests with the DOE and the USGS.

The NPS and the State of Alaska have asked the GRDO for bonds to ensure that funds will be available to clean up accidents and to properly abandon the site. The GRDO, the DOE/OBES, and the USGS are currently reviewing various alternatives to bonding that will provide these assurances. As a first step the project proposes to reserve $100,000 for accident mitigation and a reserve sufficient funds for a two- to three-year monitoring program.

4.0 GENERAL DESCRIPTION

4.1 Overview of Geological and Surface Features

The drill site at Novarupta Dome is located in Alaska, Range 36 West, Township 22, Section 15, in the southwest quarter. The ash-flow or remote site is in Range 36 West, Township 22, Section 8, in the northwest quarter.

The surface of the vent consists entirely of products of the three-staged eruption in 1912. During approximately 60 hr in June 1912, approximately 7 mi^3 (30 km^3) of pumice and ash representing approximately 3.4 mi^3 (14 km^3) of unvesiculated magma erupted. This was the largest eruption of the century and the largest rhyolitic eruption in 1,800 years. The first stage produced rhyolitic air-fall tephra and the rhyolite-rich ash-flow sheet that covered the Valley of Ten Thousand Smokes. The second stage produced dacitic air-fall tephra with subordinate andesitic air-fall tephra. During this stage, the inner vent feature known as the tephra ring formed. The final stage was the extrusion of the predominantly rhyolitic Novarupta Dome itself. The proposed core holes at the dome site are expected to encounter vent-filling facies of pyroclastic units, the intrusive feeder of Novarupta Dome, and the vent wall. They should also encounter intact (nonfragmental) intrusive equivalents of the pyroclastic units.

The surface of the vent has a moderate relief of approximately 300 m (1,000 ft). There are gently rounded landforms, and erosion has formed numerous deep gullies in the tephra deposits (Figure 4-1). The ground is loose, coarse pumice, which has been reworked in places by wind and water. Exceptions to the coarse pumice ground are the hard, blocky surface of Novarupta Dome, the soft clayey surface of scattered thermal areas, and numerous areas of moss or a moss and lichen combination.

The tephra ring is eroding. Alluvium consisting of pumice and ash is flowing inward and outward from the tephra ring. The interior of the tephra ring is filling in. The proposed drill sites and campsites within the ring rest on approximately 100 ft of fill. Since 1912, fault scarps in tephra in the vent region have largely degraded from vertical to the angle of repose and about 100 ft of fill has accumulated in the central vent basin that was shed off the tephra ring. Although the rate of erosion has declined since 1912, much of the project site is repaved annually by alluviation; therefore, the present surface is transitory.

Drilling activities will be confined within the bare pumice and ash in actively alluviating areas as much as possible. All project activities will be confined to bare pumice ash where possible. As a result, disturbance to vegetation will be minimal.

The target of the core hole at the ash-flow site is the ash-flow sheet. The vicinity has low relief (several feet); normally dry channels connect with the River Lethe. The surface material is primarily reworked pumice and ash. There is little vegetation.

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Figure 4-1. Photo of the Tephra Ring Enclosing Novarupta Dome. The drill site and campsite are out of view on the far side of the Dome. Gullies signifying erosion can be seen in the inner and outer portions of the tephra ring.

The waterline (Chapter 8) mainly traverses air-fall material near Novarupta Dome. In places closer to Lake Mageik, the underlying sintered tuff is exposed. Water, reworked ash, and glacier-ground Mageik lava is encountered at the lake and a boulder field is in the lake region. Little or no vegetation is encountered over the waterline route.

4.2 Additional Topographic Maps

A topographic map showing the location of both drill sites, the camp, and the water sources is shown in Figure 4-2. Proposed drill site and campsite locations are shown in Figures 4-3 and 4-4.

4.3 Drilling Site Layouts

The proposed drill pad at the Novarupta Dome site is in a level area northeast of the dome and within the tephra ring (Figures 4-3 and 4-4). Views of the proposed pad from the top and middle of the tephra ring are shown in Figure 4-5. The expanse of reworked pumice is sufficient for drill pad construction. Thus the vegetated areas (Figure 4-6) within the dome will generally remain undisturbed. Nonetheless, it will be necessary to put additional water storage in the vegetated area for well safety. However, this vegetated area continues to contain a large percentage (greater than 50 percent) of bare, reworked pumice surface. Water storage will be confined to these areas of rare pumice as much as possible. Figure 4-7 shows typical coarse pumice at the proposed dome drill site.

The location of the ash-flow site in the valley is shown in Figure 4-8. The ash-flow drill site is shown in Figure 4-9. The River Lethe is in the background of the top photograph. Fumaroles are on both sides of the riverbank. The River Lethe itself is shown close to the ash-flow site in the bottom photograph.

Site layouts required to support the operation are provided in Figures 4-10 and 4-11 and are detailed in Chapter 8.0. The boundary of Novarupta Dome was estimated from survey data; it was not surveyed directly. The elements of a drill site that are necessary to accomplish the drilling and coring of the core holes are provided. The horizontal dimensions of each element are indicated on the figures. The maximum height of equipment at the dome site will be the 70-ft height of the rig mast. Most structures other than the rig will be less than 12 ft high. Tents will be less than 10 ft high, although local topography, especially at the campsite, may add an additional effective maximum height of 5 to 6 ft. (The drill site at Novarupta Dome and the campsite are side-by-side and share many common elements [see Chapter 8].) At the ash-flow site the maximum height will be the 40-ft height of the rig mast. Contouring will add a maximum of 2 ft at the dome site. The elements shown in these layouts are described in Chapters 7.0 and 8.0. Drilling and coring are discussed in Chapters 7.0 and 8.0.

4.4 Field Camp Layout

The campsite will be laid out on the gradually rising area within the tephra ring (Figure 4-12). Despite this grade, the camp construction will

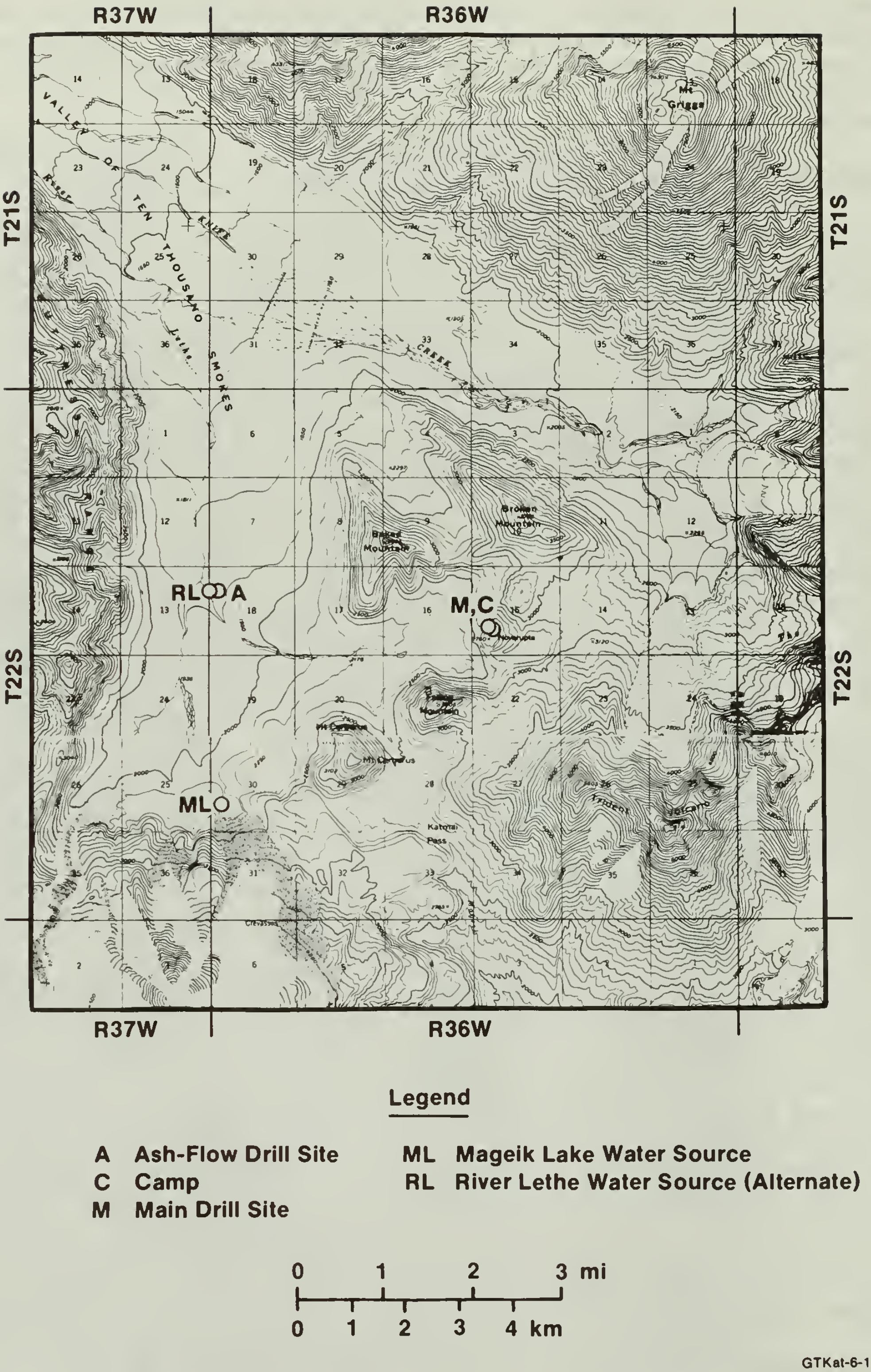

Figure 4-2. Topographic Map Showing the Dome Drill Site, the Ash-Flow Drill Site, and Potential Water Sources (Mageik Lake and the River Lethe)

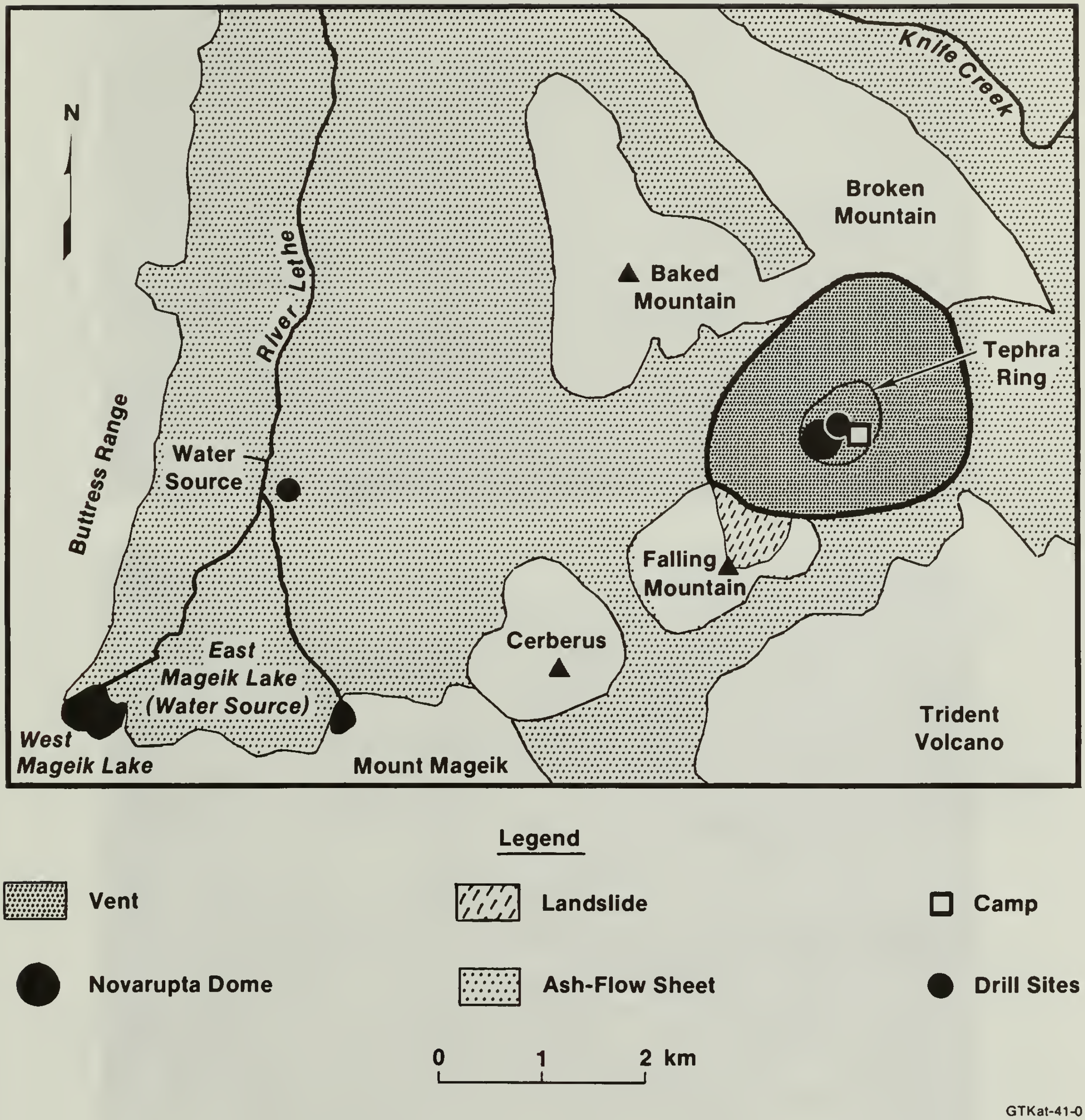

Figure 4-3. Drill Sites, Camp, and Prominent Landmarks

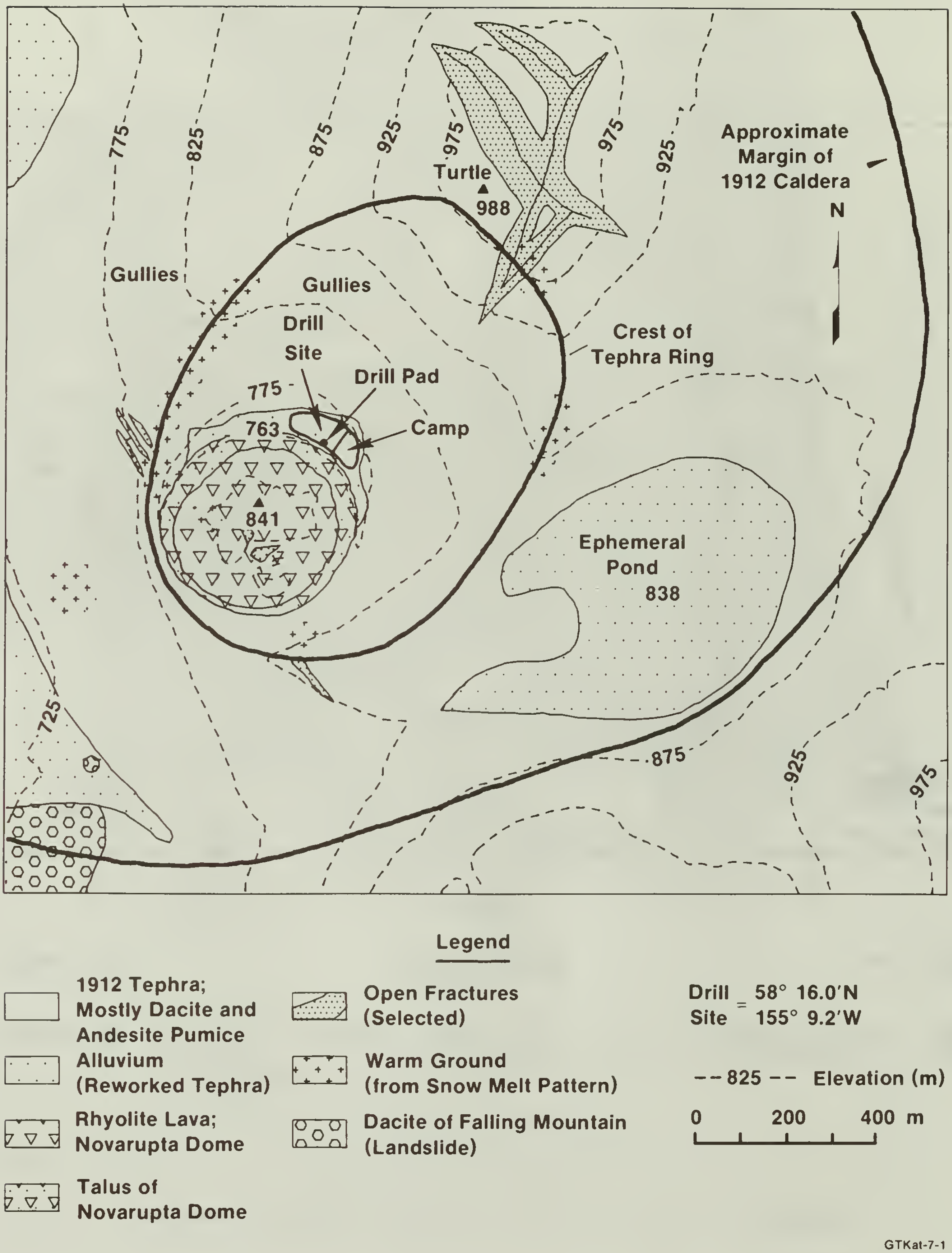

Figure 4-4. Locations of the Drill Site and Campsite Near the Dome

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Figure 4-5. Views of the Proposed Drill Site From the Top of the Tephra Ring and Halfway Down the Tephra Ring. Base of Novarupta Dome to the left.

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Figure 4-6. Vegetated Area North and East of Novarupta Dome Within the Tephra Ring

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Figure 4-7. Reworked Pumice Expanse at the Proposed Dome Drill Site

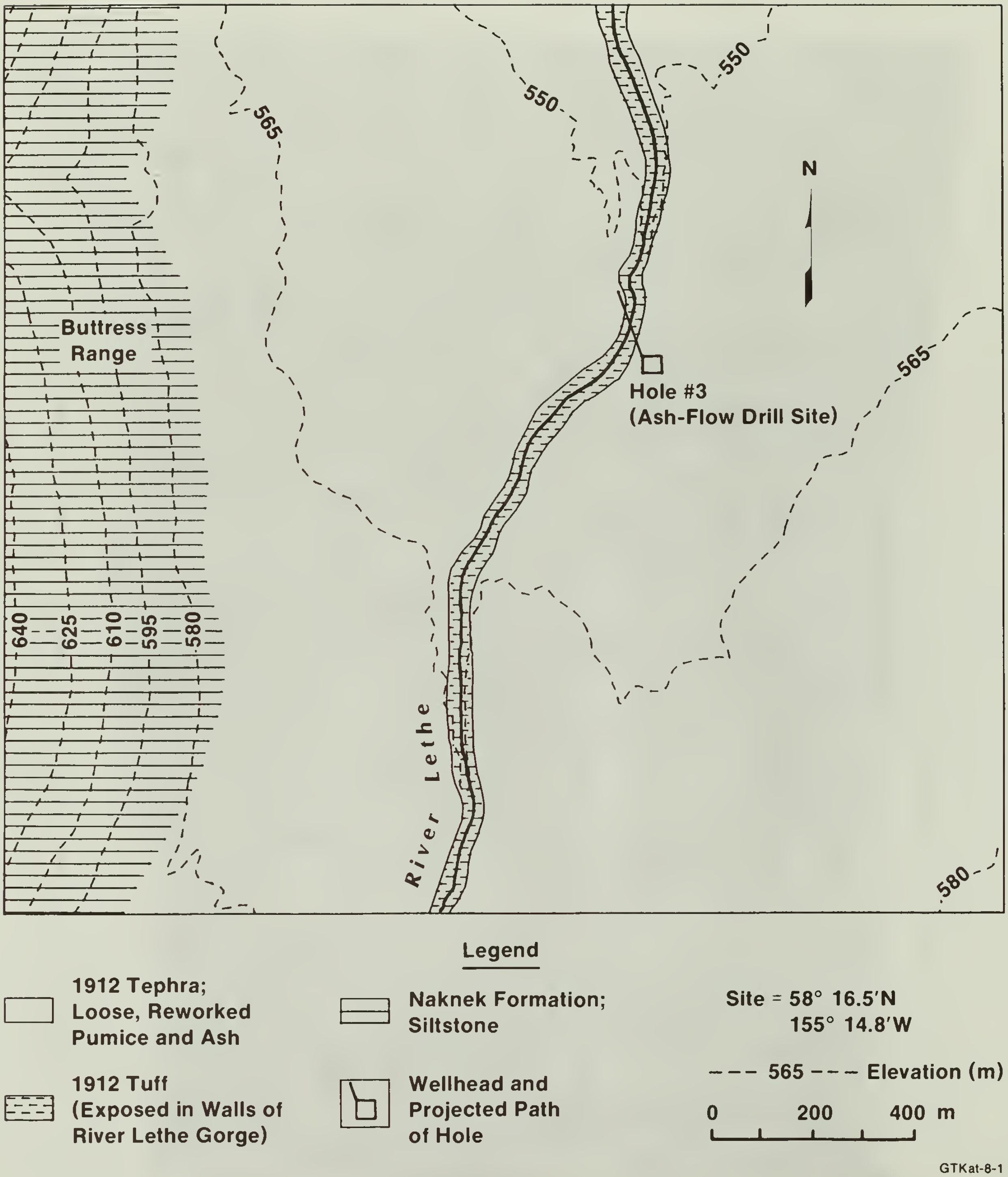

Figure 4-8. Location of the Ash-Flow Site

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Figure 4-9. Views of the Ash-Flow Drill Site and the River Lethe near the Site. Fossil fumarole vents (no longer active) are on both sides of the River Lethe.

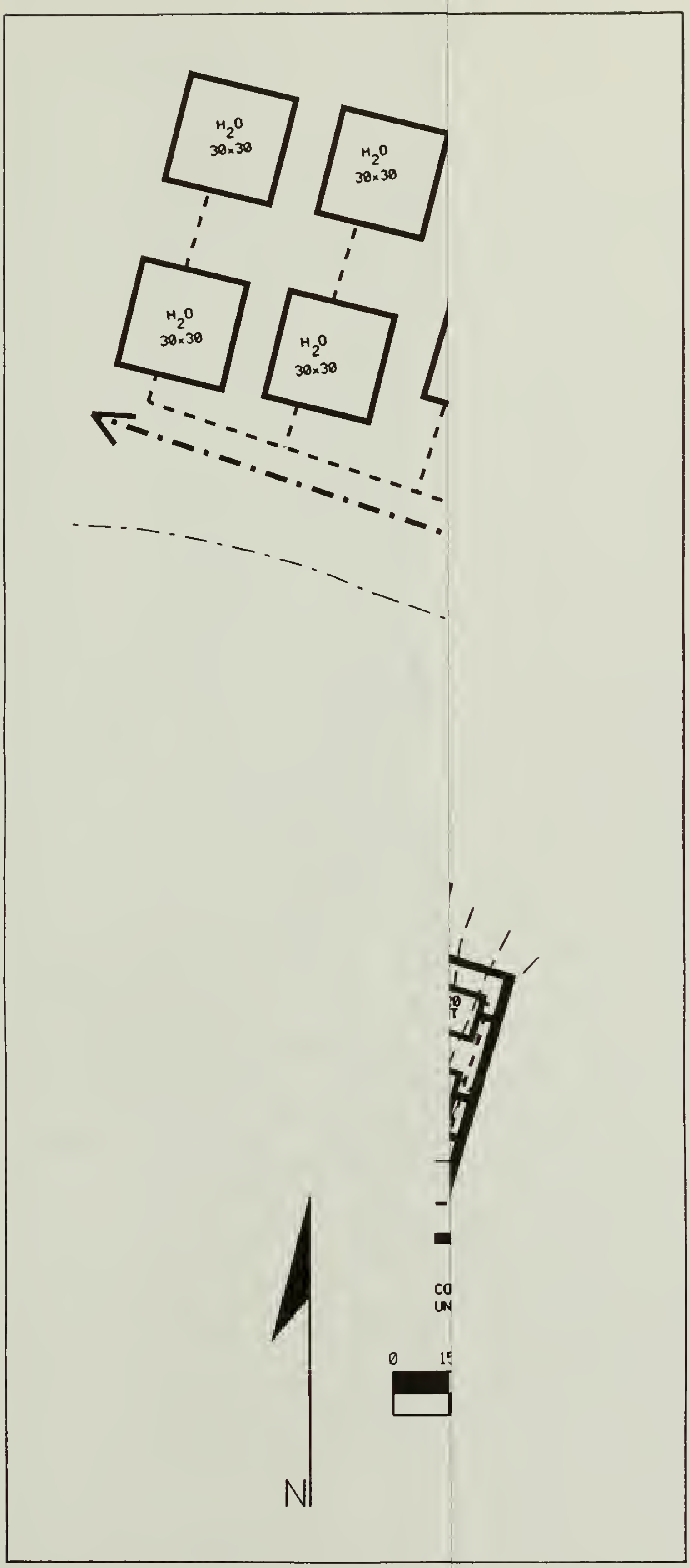

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Figure 4-10. Proposed Layout of the Dome Drill Site and Supporting Field Camp

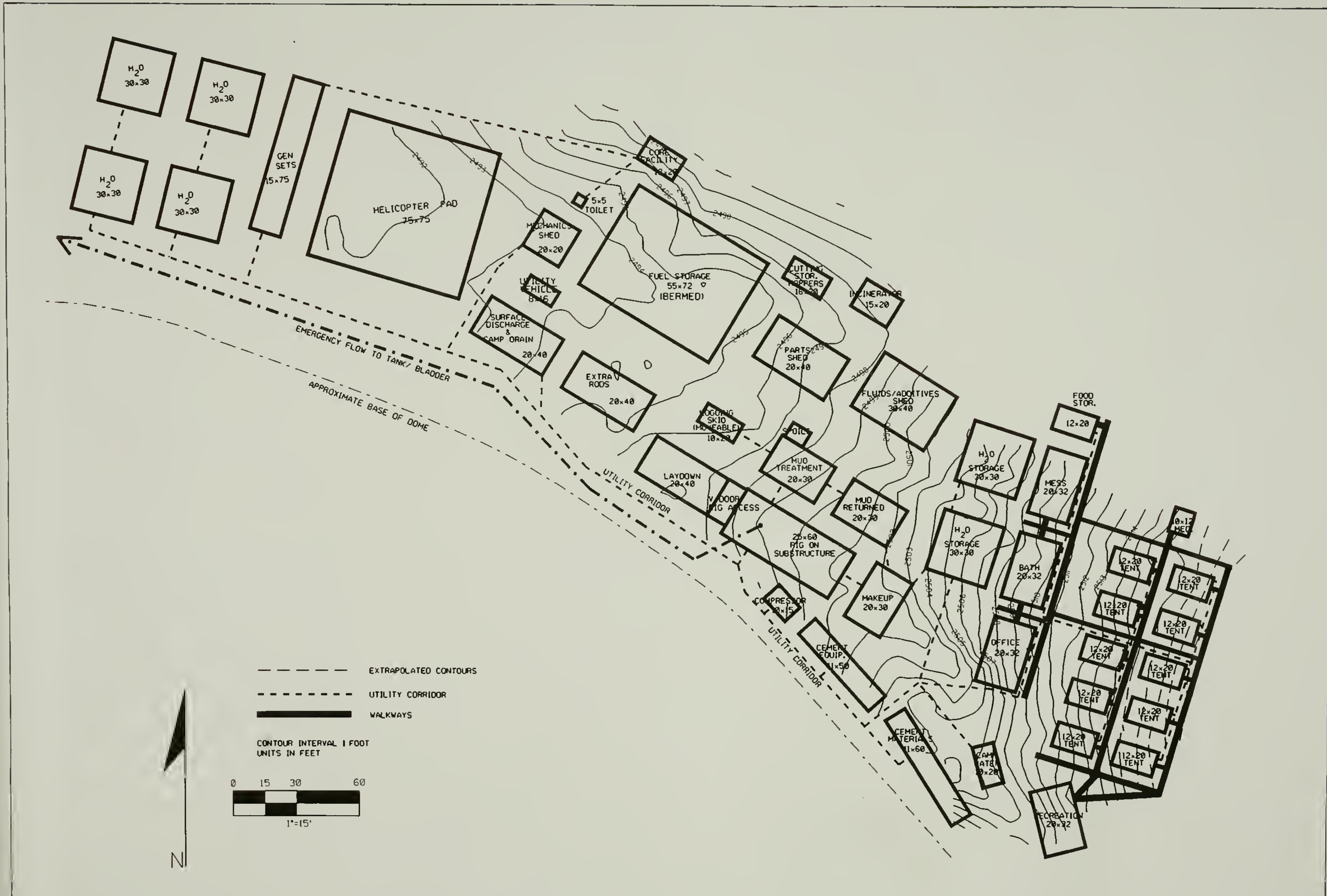

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Figure 4-10. Proposed Layout of the Dome Drill Site and Supporting Field Camp

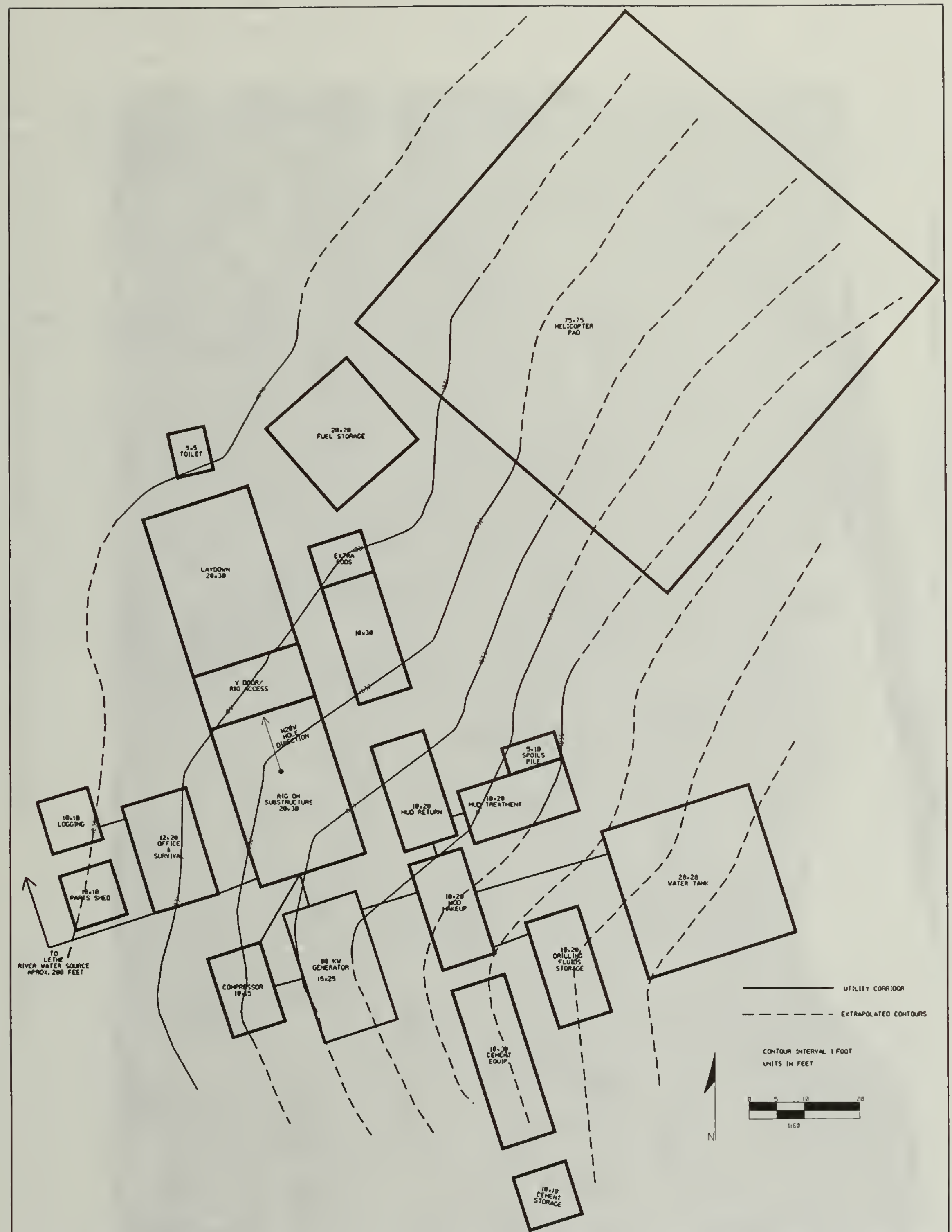

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Figure 4-11. Proposed Layout of the Ash-Flow Site

GTKat 48-0

Figure 4-12. Reworked Pumice Expanse for the Campsite

cause minimal excavation. (See Chapter 12.0 for camp details.) The surface of this area also contains course, reworked pumice. The area contains little or no vegetation except where the tephra ring rises steeply. This particular area is covered with a moss-lichen combination, cryptograms, as shown in Figure 4-5 (top). Generally, this area will be avoided because of increased grade and vegetation. Few structures will impinge on this surface. (In comparison, the earlier version of this Operational Plan proposed that the camp location would be outside the tephra ring and close to the ephemeral pond [Figure 4-4] with a pathway over the tephra ring joining the two sites. The newly proposed location of the camp avoids access across the tephra ring, and will avoid inevitable short trips by helicopter from outside to inside the tephra ring and back. Foot or helicopter travel back and forth over the tephra ring in inclement weather would have raised a serious safety issue.) If desired, vegetation transects will be established under NPS supervision to determine the impacts to the site and recovery in later years.

4.5 Discussion of Access Routes

Pedestrian access will be controlled in the operations areas. Specific pedestrian routes will be used at the campsite (Figure 4-10). At the drill sites, access will be limited to operation and equipment areas at the sites (Figures 4-10 and 4-11). Decking material such as wooden planks or cement blocks, and wooden stairways will be used to minimize disturbance to natural contours and plant life. A single unmarked pathway will be used for maintenance of the waterline. Operational access routes will be limited between the camp and the dome drill site.

5.0 GEOLOGICAL SITE DESCRIPTION

5.1 Vent Drill Site

To study the vent of the 1912 eruption, the drilling of two core holes is planned. These core holes will be used to penetrate and sample the vent interior. No permanent bodies of water exist within the vent region, although a pond is sometimes present east of Novarupta (Figure 4-2).

5.1.1 Vent Structure

Surface structures representing the three eruptive stages are concentrically arrayed. The erupted volumes decrease with time in order-of-magnitude steps. Surface expression for the stage 1 vent is interpreted to be a concentric system of open fractures of an approximately 0.6-mi (1-km) radius. The stage 2 vent is clearly expressed by a tephra ring. The stage 3 vent is the extrusion point of the lava dome, which is indicated by surface topography to be beneath the dome's center. The vent structures are presumed to be nested as depicted in Figure 1-1.

Based upon geologic, geophysical, and gas-dynamic considerations and a presumed analog (Hildreth, 1983; 1987; Eichelberger and Hildreth, 1986; Goodliffe et al., 1991), the vents for the explosive stages appear funnel-like. Lithology of ejected wall rock fragments limits the excavated volume to within the Naknek siltstone formation, the base of which is within approximately 5,000 ft (1,500 m) of the surface (Hildreth, 1987). Volumetric considerations of wall rock deposits in near-vent and vent fill deposits suggest that the vent may flare near the surface (Figure 1-1) or the fractures may mark a zone of subsidence, with the underlying vent funnel wholly contained within it. Interpretation of recent geophysical surveys also suggest a strongly flared funnel (Section 5.4). This indicates that an approximately 3,300-ft-long (1,000-m) hole slanted radially outward from the center of the vent system will reach the vent wall.

A further constraint on the subsurface geometry of proposed vent structures is the lithology of wall rock fragments in stage 2 ejecta, which are dominantly vent fill from stage 1 rather than Naknek Formation. The volume excavated in stage 2 must lie within the stage 1 vent, as depicted in Figure 1-1. Finally, the subsurface feeder for Novarupta Dome is expected to be a rhyolite intrusion that is a few tens of meters thick and is expected to be located directly beneath extensional features on the dome's surface. This expectation is based on the examination of eroded volcanoes of this type and on drilling experience at Obsidian Dome in California (Eichelberger et al., 1985). Thus surface geology and analogies to other eroded or drilled systems suggest general constraints in the subsurface configuration at the vent. However, the cross section shown in the figure remains speculative. Testing this postulated vent model is one of the objectives of drilling. (See Chapter 6.0.)

5.1.2 Expected Formations at the Vent

Three types of geologic materials are expected to be encountered in the vent. The most abundant will be the vent-filling facies of the pyroclastic

units. This will be tuff-like and will consist of variably welded mixtures of pumice, ash, and wall rock fragments. Because of the flow regime in which it forms, the vent fill will be coarser and will contain more dense components than the equivalent eruptives. Much of the vent fill is probably densely welded, but unwelded zones of unknown thickness (possibly a few tens of meters) may occur near the surface and adjacent to the vent wall at depth. Depending on the degree of welding, the vent fill will range from material that is soft, friable, and permeable to void-free glass or its finely crystalline equivalent. Unless completely unwelded or highly altered material is encountered, the vent fill will drill readily and form a stable hole. Examples of moderately-to-densely welded vent fill occur as fragments in the late ejecta. The last-ejected of these are thought to represent samples of the system no more than 60 hr after its inception. It is possible, therefore, that all of the vent fill subsequently welded.

Drilling beneath Novarupta Dome will encounter the rhyolite intrusion representing its conduit. This will likely be dense and largely or entirely crystalline. It may contain fractured zones, but will otherwise drill readily and form a stable hole. Other late intrusives that did not vent to the surface may be encountered (Goodliffe et al., 1991). In addition, the intact, intrusive equivalent of the pyroclastic units are present at some depth. Theoretical consideration of conditions for magma fragmentation suggests that such intrusives should be encountered by the vertical hole, hole 1 (Figure 1-1).

Finally, drilling may encounter blocks slumped from the vent walls. The Falling Mountain landslide is an example, but blocks of Naknek or even Trident lavas may occur as well. For the slant hole that is to reach the vent wall, continuing to greater than or equal to 300 ft (≥100 m) into the wall will be desirable to ensure that the basement rock which is encountered (presumably Naknek Formation) is in-place wall and not slumped material. The Naknek, whether slumped or in place, should be competent and easy to drill. Difficulties with unstable hole conditions may be encountered if there are substantial nonwelded zones in vent fill adjacent to the cold Naknek blocks or wall. Unstable conditions may require redrilling or cementing of the affected interval, or the setting of casing.

5.1.3 Expected Sections

The target formations for the vent region holes are the formations comprising the vent and the vent wall. The vent region holes should extend sufficiently far into the vent wall to observe the chemical and thermal effects of the eruption on the wall rock. These formations provide a record of the eruption processes. Temperature and fluids within these formations record ongoing cooling and alteration processes. For hole 1, specific targets are the intrusive equivalents of the pyroclastic units, and for hole 2, specific targets are the conduit of Novarupta, the southwest wall of the vent, and a complete radial section through the vent fill.

Both core holes will begin in alluvium, which consists of coarse, reworked pumice. Beneath the alluvium and basal breccia associated with the lava dome, the holes will encounter coarse deposits of the late dacitic air-fall tephra. At first, this may be only weakly welded, but will probably

become densely welded within tens of meters. Hole 1 will encounter stage 2 vent fill and deeper intrusions. Hole 2 will encounter the conduit of Novarupta Dome within stage 2 vent fill and later the stage 1 vent fill, and will bottom-out into the Naknek Formation immediately outside of the vent wall.

5.1.4 Conditions at Depth

Conditions at depth are unknown. There has been no previous drilling in the area or in any directly comparable area. Temperatures up to 2,200°F (1,000°C) were present at shallow depth immediately after the eruption. The maximum known surface temperature at present is approximately 190°F (~90°C) at one spot on the vent surface. Temperatures at approximately 3.3 ft (~1 m) depth at the drill site are approximately 32°F (~0°C). Since this is clearly a recharge area with downward percolating water, the core holes will be cold to some unknown depth. Temperatures well above boiling, pressures above hydrostatic, and toxic gases such as hydrogen sulfide may exist at depth. Precautions to mitigate these hazards are discussed in Sections 10.2 and 10.4.

5.2 Valley Drill Site

The geology of the proposed drill site (Figure 4-3) on the ash-flow sheet is expected to be simple. The site is on the surface of the ash-flow sheet from the 1912 eruption, which filled a glacial valley to form the Valley of Ten Thousand Smokes.

5.2.1 Expected Sections

The target formations are the ash-flow sheet and the pre-1912 valley floor. The tuff sheet is covered by a veneer of variably eroded, late dacitic air-fall tephra (Figure 5-1). These eruptive products from the 1912 eruption in turn, overlie fluvial deposits of the ancestral (pre-1912) River Lethe, glacial till, and Naknek Formation basement. Several attempts have been made to estimate the thickness of the ash-flow sheet, (Curtis, 1968; Ward and Matumoto, 1967; Kienle, 1991; 1970, 1969). A topographic estimate of the thickness of the ash-flow sheet at the proposed site (based on stream profiles) is approximately 700 ft (210 m) at the proposed drill site (Curtis, 1968) and an estimate of the thickness from gravity data is 460 ft (140 m). If the sag in the surface of the sheet in its vicinity is attributed solely to welding that followed emplacement, then the average compaction of the section is 30 percent at the drill site. Stream cuts show, however, that even the nonwelded portions of the sheet are sufficiently sintered to support vertical faces. The core hole is therefore expected to be stable within the tuff. The top few meters of the hole in the air-fall tephra veneer will be unstable. A section of conductor pipe will be set to facilitate penetration through this unstable layer (Chapter 7.0). Drilling may be difficult and the hole may be unstable in the glacial and fluvial debris of unknown thickness underlying the sheet. An effort will be made to reach greater than or equal to 100 ft (≥30 m) below the ash-flow sheet to assess thermal and chemical effects of the eruption upon the substrate.

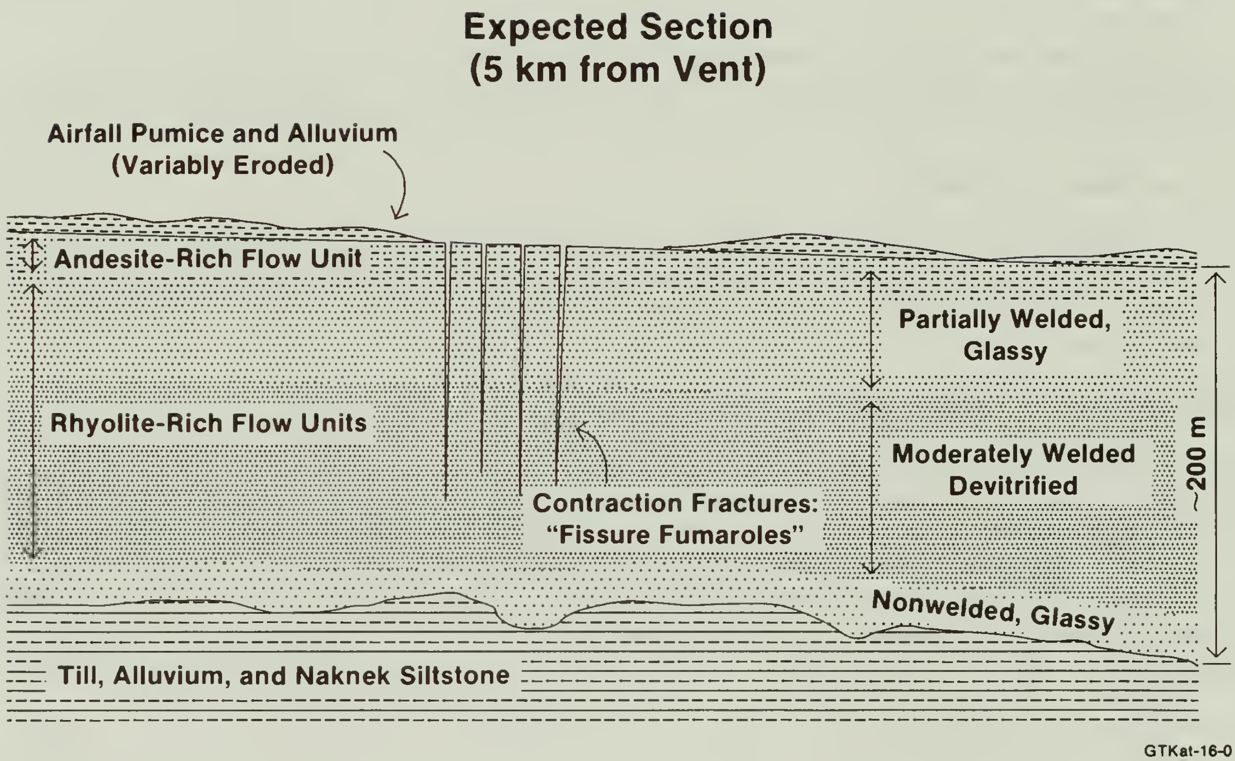

Figure 5-1. Section at the Ash-Flow Sheet Drill Site

5.2.2 Geologic Structure

The only structures evident in the vicinity of the site are linear fumarole-mound ridges arrayed a few tens of meters apart, which are roughly perpendicular to the valley axis. Based on exposures cut by the River Lethe, these are interpreted as the tops of deep vertical fractures that served as pathways for hot metal-laden gases during the first several years following emplacement of the tuff (Keith, 1984). The hole will be slanted perpendicular to the trend of these fractures to intersect them at multiple depths. This will permit study of metal release, transport, and disposition through the vertical extent of the vapor-transport system. Water is present at the River Lethe several tens of meters from the drill site during the summer and fall.

It is unlikely that toxic gases continue to be released from the deposit because this site is well removed from the source vent and therefore cold or merely warm. Figure 5-2 shows fumaroles and vertical fractures in the immediate vicinity of the ash-fall drill site in the valley.

5.3 Geochemistry and Hydrology

5.3.1 Element Analysis of Typical Rock Samples From the 1912 Eruption

Table 5-1 gives chemical analyses of rock samples from Falling Mountain, Mt. Cerebus; from various portions of the 1912 eruption; and from Novarupta Dome. These rock types should be typical of lithologies to be encountered while drilling the proposed wells. They are considered typical of many expected sections of the two wells described in Sections 4.1, 5.1, and 5.2 and in Figures 1-1 and 5-1. Thus this table includes analysis of rock from the early basal (rhyolitic) air fall; the early pyroclastic basal (rhyolitic) ash flow; the later, topmost (more dacitic, andesitic) ash flow; two later dacitic air-fall layers; and lava from Novarupta Dome (Hildreth, 1983; Curtis, 1968). These analyses of rock samples from the stages of the Katmai eruption do not presuppose the composition of samples to be found at depth. Rather, they provide an estimate of the elemental concentrations that may be found in various strata.

Similarly, Table 5-2 provides the ranges of trace element data for rhyolitic, dacitic, and andesitic pumice that may be found in many of the sections of the two wells described in Sections 4.1, 5.1, and 5.2 and Figures 1-1 and 5-1. Devitrification and fumarolic deposition can alter these ranges (Hildreth, 1987; Keith, 1991), and data from this drilling project will show the extent of these alterations with depth.

Samples from the Valley of Ten Thousand Smokes were analyzed according to EPA protocol, the Toxicity Characteristic Leaching Procedure (TCLP) under 40 CFR 260, Part C, because the volcanic rock often contains significant concentrations of some metals listed as pollutants under the RCRA. Total concentrations of these RCRA metals were also analyzed so a relationship could be obtained between the TCLP leachate and the total amount of a metal available for leaching. Samples included the following:

GTKat-17-1

Figure 5-2. Approximately 4-Ft-High Fumaroles (Left) and a Contraction Fracture in the Vicinity of the Ash-Flow Site (Right)

Table 5-1

Chemical Analyses of Rock Types From the Three Stages of the 1912 Katmai Event and Related Rocks*,**

	Pre-1912 Domes		1912 Ejecta					Novarupta Dome		
	Falling Mtn.	Mt. Cerberus	Base of Rhyolitic Air Fall	Basal ash flow	Topmost ash flow	Top of Early Dacitic Air Fall	Top of Late Dacitic Air Fall	Purest rhyolite	Crystal-poor band	Crystal-rich band
SiO_2	64.2	64.0	77.4	77.3	58.6	64.6	62.9	76.9	76.6	65.1
TiO_2	0.62	0.63	0.17	0.17	0.71	0.71	0.72	0.17	0.23	0.71
Al_2O_3	16.2	16.2	12.4	12.35	16.9	15.65	16.2	12.5	12.55	15.5
Fe_2O_3	2.59	2.33	0.39	0.44	2.96	1.97	2.00	0.55	0.48	1.91
FeO	2.72	3.03	0.85	0.81	4.16	3.44	3.78	0.89	1.04	3.50
(FeO**)	5.05	5.13	1.20	1.21	6.83	5.21	5.58	1.39	1.47	5.22
MnO	0.10	0.10	0.05	0.05	0.14	0.12	0.13	0.05	0.06	0.12
MgO	2.20	2.34	0.11	0.09	3.80	2.14	2.65	0.02	0.08	1.95
CaO	5.15	5.22	0.87	0.93	7.31	4.97	5.67	0.95	1.13	4.85
Na_2O	4.19	4.13	4.25	4.21	3.54	4.20	4.01	4.36	4.36	4.21
K_2O	1.60	1.56	3.20	3.25	1.29	1.74	1.57	3.22	3.10	1.68
P_2O_5	0.13	0.14	0.03	0.03	0.13	0.135	0.13	0.02	0.04	0.15
F	-	-	500	500	400	400	-	500	-	-
Cl	20	<10	1375	800	800	700	630	1125	950	500
S	<10	<10	<10	80	140	150	240	60	10	180
Sr	303	320	40	47	327	237	240	52	58	215
Ba	595	575	990	1025	410	600	530	960	950	550
V	112	105	<2	<2	175	105	120	<2	4	102
Y	28	26	46	42	7	24	15	48	40	13
Zr	117	110	158	157	113	151	145	157	146	165
La	12	12		18.5	11	13.5	12		18.5	13
Ce	25	26		41.5	24	29	28		42	30
Nd	14	15		23.5	14	16	16		23	17
Sm	3.5	3.5		5.6	3.8	4.25	4.2		5.7	4.4
Eu	0.90	0.91		1.01	0.97	1.24	1.26		1.0	1.3
Tb	0.64	0.64		1.03	0.62	0.76	0.75		1.05	0.82
Yb	3.0	3.0		4.7	2.8	3.45	3.3		4.8	3.5
Lu	0.46	0.45		0.61	0.42	0.54	0.50		0.64	0.54

*All data are normalized to 100%, H_2O-free; major elements in wt%, others in ppm.

**All samples of 1912 ejecta were pumice blocks, the Novarupta samples microvesicular vitrophyres, and the two precaldera samples nonvesicular vitrophyres. Major elements and Cl through Zr were analyzed by XRF, USGS laboratories at Menlo Park; FeO by titration; F by specific-ion electrode; REE and lower list (Rb through Zn) by INAA at Lawrence Berkeley Laboratory by methods of Perlman and Asaro (1969). Total H_2O contents by Penfield analysis are given at the bottom.

Table 5-1 (Concluded)

Chemical Analyses of Rock Types From the Three Stages of the 1912 Katmai Event and Related Rocks (Concluded)

	Pre-1912 Domes		1912 Ejecta					Novarupta Dome		
	Falling Mtn.	Mt. Cerberus	Base of Rhyolitic Air Fall	Basal ash flow	Topmost ash flow	Top of Early Dacitic Air Fall	Top of Late Dacitic Air Fall	Purest rhyolite	Crystal-poor band	Crystal-rich band
Rb	29	29		71	20	38	-		71	29
Cs	0.7	0.5		3.6	1.2	1.5	1.5		2.8	1.4
Ba	550	570		975	440	625	580		995	600
Th	2.8	2.8		5.65	2.9	3.25	3.35		5.6	3.2
U	1.2	1.3		2.5	1.3	1.4	1.5		2.55	1.5
Hf	3.4	3.4		5.3	3.2	4.5	4.5		5.2	4.5
Ta	0.30	0.29		0.52	0.3	0.33	0.34		0.49	0.34
Sb	0.6	0.3		1.1	0.5	0.6	0.6		0.9	0.6
Sc	15.5	16.6		7.8	25.0	18.3	17.6		8.7	19.5
Cr	5.1	7.0		2	27	8	9		1.6	6
Fe%	3.85	3.99		0.91	5.27	3.95	-		1.15	4.00
Co	11.5	12.4		-	18	-	-		1.6	-
Zn	65	62		37	85	73	72		30	86
(H_2O)	0.25	0.18		2.66	2.88	0.88	2.52	1.56	0.26	0.40.26

Table 5-2

Trace Element Data for the Major Pumice Types in the Valley of Ten Thousand Smokes (ppm)

	Rhyolite	Dacite	Andesite
Li	33, 38	20, 21	16, 19
Li	31, 34, 43, 45, 49, 52, 56	17, 19, 21, 22, 24, 25,26	17, 20, 21
Be	1.5, 2.0	0.8, 0.5	0.6, 0.6
B	31, 36, 40, 42, 51, 54, 58	28, 35, 41, 41	<4
Cu	<10	15, 21	15, 22
Cu	3, 4, 6, 6, 7, 7, 11	14, 18, 21, 23, 31, 31, 39	26, 36, 43
Ga	12, 12, 12 15, 15, 16, 16	21, 22, 22, 23, 24, 25, 28	27, 28, 29
Nb	5.2, 5.4	5.6, 4.8	4.6, 4.9
Mo	2.8, 2.9	1.6, 1.7	1.4, 1.5
Sn	1.8, 2.0	0.6, 1.0	0.9, 1.8
W	0.86, 0.98	0.40, 0.46	0.36, 0.50
Pb	13, 14	7.6, 9.0	6.3

- 1912 dacite, andesite, and rhyolite ash flow tuff with lithics of andesite,

- 1912 dacitic pumice,

- 1912 andesite and dacite pumice, and

- portions of a fumarole at the ash-flow site. Concentrations of metals and some RCRA metals in particular can increase well over that of the surrounding volcanic rock.

In spite of an elevated sample concentration of some RCRA elements in certain samples (Appendix C) (e.g., the lead concentration was over 1,000 ppm in one case), no leachate was even detected, except for 0.64 ppm of barium. This is more than two orders of magnitude below statutory limits. While the tests do not include every conceivable volcanic sample, no RCRA leachate was even detected in the samples tested (except for the minute amounts of barium already mentioned). These samples had significant amounts of lead, barium, chromium, and detectable cadmium and arsenic. The limits of detection for these tests are fairly sensitive (Appendix C).

These data (Appendix C) strongly suggest that <u>RCRA Subtitle C hazardous waste concerns will not be an issue for the Katmai core, cuttings, or other samples</u> brought up from drilling or coring. Furthermore, there is the statutory exclusion for drilling solids, scientific samples, and liquids under

the RCRA Subtitle C program. These materials are appropriately regulated under the Subtitle D program of RCRA.

5.3.2 Hydrology

Because of its porous and somewhat fractured character, the lower part of the ash-flow sheet in the Valley of Ten Thousand Smokes serves as an aquifer. The aquifer exists just above the interface of the ash-flow sheet with the relatively impermeable Naknek siltstone (Figure 5-1), which is approximately 3,300 ft (1,000 m) thick in the Valley of Ten Thousand Smokes. Vigorous springs pour from its base near the terminus of the sheet (Figure 5-3). Some of these springs contain a thermal component. Evidence shows that the welded portion of the ash-flow outflow sheet retains some heat at depth.

Extensive water sampling was accomplished from 1979 through 1989 in rivers, streams, and springs in the vicinity of Novarupta Dome, with the heaviest concentration in the ash-flow sheet itself (Figure 5-3, Table 5-3) (Keith et al., in preparation). Conclusions from the sampling are listed below.

- Streams and Rivers Fairly high concentrations of Cl^-, F^-, SO_4^{--}, and HCO_3 that were observed at some stream and river sampling stations appear to emanate at least in part from leaching of the ash-flow sheet rather than directly from the hydrothermal system associated with the nearby volcanoes or from warm thermal springs discussed in the following section.

    - The concentrations of the above ions depend on the volume of drained ash-flow tuff. The concentration of the ions do not depend on the temperature of the waters in the streams and rivers.

    - The concentration of these ions are low for stations where the drainage emanated from outside of the sheet (sites 8, 14, 22, Figure 5-3, and Table 5-3), or where there is a small volume of drained ash-flow tuff (sites 15 through 19, 24 through 29, Table 5-1, and Figure 5-2).

    - Concentrations of these ions are high at stations where a fairly large volume of ash-flow tuff within the sheet had been drained (sites 1 through 5, Figure 5-2).

- Springs These data suggested more than one hydrological system. There may be a rough correlation of the temperature with enhanced concentrations of the above ions in certain springs. Reasons for more than one hydrological system are the following:

    - Observations over the years suggest that the flow of the cold springs above and within the ash-flow sheet is a function of precipitation. The fresh water system flows within the somewhat porous ash-flow sheet and at the base of the ash-flow sheet, which lies above a relatively impermeable 3,300-ft-thick Naknek siltstone.

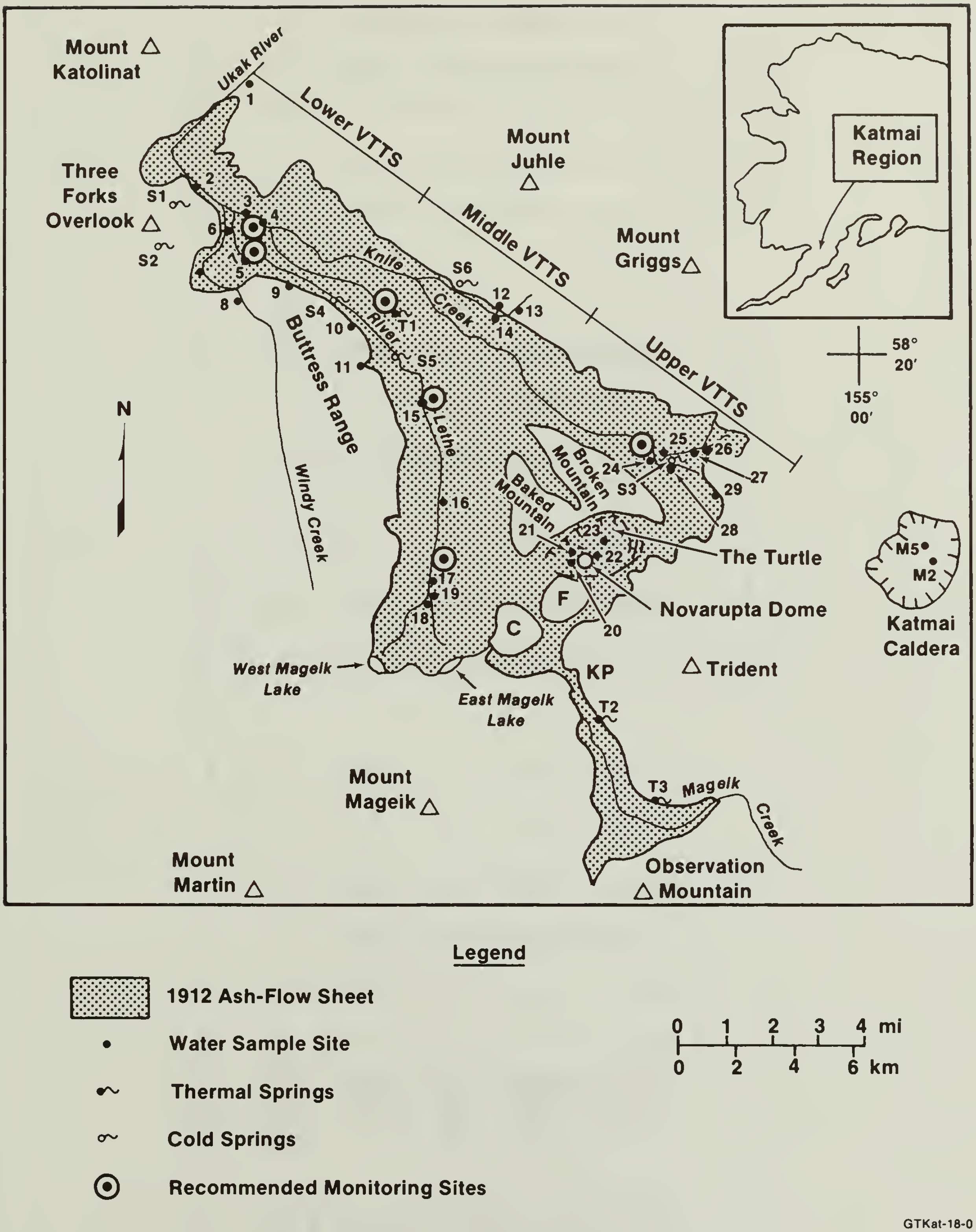

Figure 5-3. Earlier Water-Sampling Locations and Proposed Monitoring Locations

Table 5-3

Water Analysis in and Around Valley of Ten Thousand Smokes

Map No.	Location	Date	Temp	Field pH	Lab pH	SiO_2	Fe	Mn	As	Ca	Mg	Sr	Ba	Na mg/L	K	Li	Rb	Cs	HCO_3	SO4	Cl	F	B	Conductivity µS/cm
Upper Knife Creek																								
24	head of Knife Creek	26 Aug 89	2.9	5.3	4.06	51	38.4	0.43		23.6	5.22	0.128	0.023	6.34	0.99	0.007			0	87	3.1	0.79	<0.05	205
25	blw glaciers 4,5	26 Jul 82	5	5.4	4.18	10.6		0.12		16.6	1.87			2.85	0.5	<0.01	0.03	0.03	5	32	1.5	0.46	0.25	264
26	blw glacier 5	26 Aug 89	4.5	5.9	4.42	40.9	26.36	0.3		14.7	3.23	<0.05	<0.05	4.9	0.68	0.005			5.8	46	1.9	0.51	<0.05	120.8
27	draining glacier 4	26 Aug 89	2.6	4.2	3.98	28.6	1.36	0.39		34	2.58	0.093	<.05	6.82	0.38	0.007			0	106	1.9	1.83	<0.05	292
28a	blw glaciers 1,2,3,4	1 Aug 86	3	5.2	3.92	13.3				22.7	2.9			3.8	0.34	0.01			0	62	3.4	0.22	0.05	246
28b	blw glaciers 1,2,3,4	26 Aug 89	3.7	5.3	4.45	38.5	10.18	0.19		21.1	2.6	0.046	<.05	6.51	0.64	0.011			9.1	79	3	3.15	<0.05	187.7
29	blw glaciers 1,2,3	26 Aug 89	0.7	5.9	3.87	51.2	39	0.4		20.7	6.62	<.05	<.05	10.9	1.26	0.007			0	111	5.1	0.32	<0.05	268
S3	cold spg in up Knife Cr	6 Aug 84	10	5.7	6.27	25.7				24.1	2.15			8.1	0.5	<0.01			25	58	5	1.8	0.15	224
Lower Knife Creek																								
3a	at 3 Forks	12 Aug 82	11	5.9	7.09	28.4		0.13		56.4	11.59	0.14		42.5	2.37	0.08	0.05	0.34	55	140	57	1.6	0.3	565
3b	at 3 Forks	19 Aug 89	7.8	5.3	5.68	86.6	38.66	0.39		42	14.6	0.24	0.06	39.6	2.4	0.068			26.4	100	33.3	1.33	0.21	440
4	abv 3 Forks	6 Aug 86	6	5.5	6.78	24				44.1	9.65			31	1.1	0.07			37	104	40.8	1.35	0.19	483
Upper River Lethe																								
15	at ford	5 Aug 86	2.5	5.3	6.49	9.8				4.4	0.94			1.5	0.15	0.007			13.8	14	1.2	0.07	0.24	44.1
16	abv ford	24 Aug 89	4.7	5.6	4.82	42.9	9.68	0.09		2.1	1.04	<.05	<.05	4.24	0.97	0.003			10.3	11	1.2	0.11	<0.05	30.4
17	abv ford	4 Aug 82	7	5.7	6.49	52.4		0.09		10.1	1.83	0.05		4	1.27	<0.01	0.04	0.08	26	13	4	0.75	0.1	53.8
18	west fork	24 Aug 89	4.1	5.4	4.72	37.1	4.69	0.07		5	0.86	<.05	<.05	3.98	0.95	0.002			12.2	10	1.5	0.12	<0.05	30.1
19	east fork	24 Aug 89	5.1	5.3	4.28	36.3	16.93	0.1		10	1.45	<.05	<.05	3.44	0.76	0.002			0	40	1.2	0.11	<0.05	33.6
Lower River Lethe																								
5a	low. Lethe	13 Aug 82	13	6	7.46	27.6		0.03		25.1	8.54	0.07		35.2	2.51	0.125	0.05	0.09	82	60	40	1.65	0.4	380
5b	low. Lethe	20 Jul 82	10	5.7	7.3	26.5				28.6	9.2			34.4	1.8	0.11			67.5	71	26.7	1.2	0.4	358
5c	low. Lethe	20 Aug 89	8.4	5.48	5.9	42.5	6.78	0.09		11.5	4.47	0.14	0.1	27.1	1.81	0.069			46	26	17.1	2.33	0.06	241
Windy Creek																								
6	below ford	20 Aug 89	14.2	7.85	5.45	15	1.34	0.03		17.5	1.62	0.11	0.04	4.28	0.57	0.002			42.5	23	2.1	0.21	<0.05	124.6
7	at ford	20 Jul 86	14	5.7	6.99	10.1				14.1	2.2			3.1	0.22	0.005			24.9	21	1.5	0.06	<0.1	102

Table 5-3 (Continued)

Water Analysis in and Around Valley of Ten Thousand Smokes

Map No.	Location	Date	Temp	Field pH	Lab pH	S_iO_2	Fe	Mn	As	Ca	Mg	Sr	Ba	Na mg/L	K	Li	Rb	Cs	HC_{O3}	S04	Cl	F	B	Conductivity µS/cm
Ukak River																								
1	at toe of ash flow	6 Aug 84	15	6.2	6.94	53.1				35.6	9.48			31.1	2.46	0.08			58	62	47	1.4	0.25	378
2a	at footbrdg	12 Aug 82	13	5.9	7.35	26.7		0.07		37.9	9.03	0.1		35.9	2.11	0.102	0.05	0.05	27	90	46	1.55	0.6	507
2b	at footbrdg	19 Jul 86	14	5.9	7.05	23.6				39.9	9.1			6.2	1.3	0.08			18.2	83	31.8	0.75	0.47	393
2c	abv foobrdg	19 Aug 89	8.4		5.51	67.9	38.66	0.39		25.9	9.17	0.17	0.03	33.4	2.08	0.066			38	101	24.9	1.4	0.13	341
Cold Springs on Three Forks Overlook Hill																								
S1a	spg on trail to Ukak R	19 Jul 82	5	5.6	7.4	19.4				16	2.98	0.03	1.53	5.26	0.5	<.01	0.02		66	20.5	2.05	0.14	0.15	140
S1b	spg on trail to Ukak R	19 Jul 86	9	5.7	7.06	19.1				18.3	3.4			4.9	0.17	0.01			46	18	2.4	0.05	<.05	128
S1c	spg on trail to Ukak R	19 Aug 89	4.8		5.39	19.2	0.11	<.01		17.3	1.89	0.041	<.05	5.19	0.52	0.004			44.7	17	2.8	0.28	<.05	125.5
S2a	spg on trail to Windy Ck	14 Aug 82	5	5.6	7.37	20.3		0.01		16.3	3.12	0.02		4.11	0.74	0.01	0.03	0.08	63	11	2.4	0.02	0.15	120
S2b	spg on trail to Windy Ck	20 Jul 86	7	5.9	6.81	19.1				14.8	3.5			4.4	0.24	0.008			48.4	21	3	0.03	0.48	120.6
S2c	spg on trail to Windy Ck	20 Aug 89	5		5.39	18.5	0.02	0.01		18.6	1.88	0.09	0.06	4.82	0.45	0.005			46.1	16	2.3	0.12	<.05	119.3
Streams Above Ash-Flow Sheet																								
8	abv ash-flow sheet	20 Aug 89	12	7.71	5.54	14.7	0.63	0.01		12.2	2.15	0.16	0.03	6.05	0.53	0.001			51.9	18	2.6	0.37	<0.05	136
9a	Fe depositing cr	13 Aug 82	12.5	5.7	7.22	20.2	1.63	0.07		11.2	2.1	0.023		4.11	0.66	<0.01	0.03	0.08	71	5	1.42	0.75	0.3	100.7
9b	Fe depositing cr	28 Aug 89	11		5.32	20.4	2.35	0.09		9.2	1.52	0.023	<0.05	4.28	0.48	0.001			46.5	5	2.3	0.17	<.05	83.6
10	stream drain Buttress	28 Aug 89	8.5	6.8	5.43	19	0.65	0.03		33.2	2.65	0.028	0.023	15.1	0.58	0.005			62	72	2.4	0.24	0.2	259
11	6 mile camp	21 Aug 89	13.1	8.06	5.41	29.5	4.85	0.08		27.3	2.36	0.17	0.1	7.03	0.62	0.005			49	35	2.2	0.22	<0.05	161
12	btw Juhle & Griggs	6 Aug 84	14	5.9	7.01	19.8				26	2.85			3.8	0.85	<0.01			58	25	2	0.19	<.1	177
13	Juhle fk stream	25 Aug 89	9.9	5.7	5.09	38.1	1.24	0.01		11.8	2.59	<0.05	<0.05	8.32	2.05	0.005			17.4	28	12	0.11	<.05	130
14	Juhle fk abv falls	25 Aug 89	6.9	5.5	4.42	97	42.35	0.59		19.7	8.15	0.089	<0.05	17.5	2.52	0.007			5.8	79	9.1	0.17	<.05	196.3
Precipitation																								
20	precip west of dome	31 Aug 89	4		4.66	2.6				0.2	0.099	<0.05	<0.05	1.08	0.09	<0.001			8.9	5	0.9	<0.1	<.05	4.5
21	Snow melt pond	28 Jul 86	14	5.2	5.44	2				0.36	0.05			0.17	<0.1	0.007			11	2	0.4	0.25	0.07	9.2
22	precip drain into dome	31 Aug 89	4		4.81	14.1				0.63	0.068	<0.05	<0.05	1.7	0.07	<0.001			10	1	1.1	<0.1	<.05	8.5
23	Snow melt on Turtle	25 Jul 82	15	5.5	5.66	0.3				0.15	0.01			1.46	<0.01	<0.01			11	<.2	0.3	0.285	0.15	7.6

Table 5-3 (Concluded)

Water Analysis in and Around Valley of Ten Thousand Smokes

Map No.	Location	Date	Temp	Field pH	Lab pH	SiO_2	Fe	Mn	As	Ca	Mg	Sr	Ba	Na	K	Li	Rb	Cs	HCO_3	SO4	Cl	F	B	Conductivity
														mg/L										µS/cm
Midvalley Thermal Springs																								
T1	spg mid (1)	24 Jul 87	15	5.7	6.73	55.5				89.5	17.9			73.3	2.96	0.16			105	330	69.6	3	0.66	
T1	spg north (2)	24 Jul 87	17	5.7	7.01	58.6				94	19.9			83	4.21	0.2			127	390	73.6	2.9	0.8	
T1	spg mid (3)	23 Aug 89	17.8	5.7	6.49	38.3	<.01	<.01	0.34	90.8	15.95	0.33	0.03	78.1	3.63	0.204	0.07	0.06	135	276	71	2.93	0.67	934
T1	spg mid (1)	23 Aug 89	17.8	5.9	5.89	38	<.01	<.01	0.23	89.9	15.84	0.297	0.03	80.6	3.63	0.204	0.06	0.06	132	279	68.4	2.84	0.461	917
T1	southmost spg (4)	23 Aug 89	17.6	5.7	6.32	37.3	<.01	<.01	0.52	89.8	15.77	0.225	<.05	78.4	3.41	0.188	0.06	0.05	127	280	67.6	2.42	0.4	906
Hot Springs South Side of Katmai Pass																								
T2	warm spg	3 Aug 82	15	5.7	8.05	67.5	20.1	1.16		33.5	31.12	0.4		98.9	7.92	0.038	0.09	0.05	190	93	145	0.102	1.65	
T2	warm spg	9 Aug 84	15	6	6.84	42.9	0.04	0.33	0.86	44	30	0.29		121	8.91	0.03	<.01	0.04	452	54	113	0.1	3.4	926
Thermal Springs North Side of Mageik Creek																								
T3	hot spg (1)	3 Aug 82	40	6.8	7.9	105	1.18	0.02	0.66	136	59.3	0.5		231	29	0.58	0.49	0.52	337	410	262	2.89	2.75	2080
T3	hot spg (2)	3 Aug 82	42	6.8	7.59	111	1.2	0.03	0.61	116	65.1	0.57		252	29.2	0.64	0.46	0.9	377	330	279	2.77	4.2	2280
T3	hot spg (3)	9 Aug 84	40	6.5	7.53	105	<.1	<.1	1.34	157	69.7	0.5		218	25	0.5	0.29	0.19	569	480	251	2.5	5.5	2040
Katmai Caldera Lake																								
M2	60 m depth in lake	8 Jul 75	5.5	3		120				300	51			760	90	0.92				1250	1350	0.9	12	
M5	60 m depth in upwelling	8 Jul 75	5.5	3		140				300	62			590	110	1.2				1200	1750	1.1	14	

As of March 29, 1990

- The cold water springs (sites S1 and S2, Table 5-3, and Figure 5-3) are relatively fresh meteoric water running directly through the Naknek siltstone. These waters may run, in part, through fractures, cracks, and joints in the siltstone. These waters are high in Ca^{++} and SiO_2, but low in Cl^-, HCO_3^-, and SO_4^{--}.

- The midvalley thermal springs (site T1 and Figures 5-3 and 5-4) have a high ion concentration (Table 5-3). The chemical composition of the midvalley thermal spring waters does not change with temperature as would be expected if water from a high-temperature hydrothermal system was mixing with cold surface water. However, oxygen and deuterium isotopic composition indicates that the thermal water is meteoric in origin. Portions of the ash-flow tuff in the midvalley could be warm. The midvalley thermal springs occur in a line of thermal springs extending over a distance of approximately 1,000 ft at a midvalley site. There are approximately 70 major orifices of these springs in the ash-flow sheet and innumerable minor orifices. Approximately 150 gal per sec of saline fluid flowing into Knife Creek from these springs are independent of the natural leaching process (Keith et al., in preparation). These springs have different temperatures both as a function of the season and as a function of the individual orifice. There are probably more thermal springs of this type in the valley, as discussed further in this section. Springs of this type may account for the majority of the salts in the Knife Creek and River Lethe system.

- Thermal springs T2 and T3 (Table 5-1, and Figure 5-2) are considered hydrothermal in nature, or at least in part. The warmer spring, T3, has by far the larger concentration of ions.

• <u>Possible Drainage Paths</u> Possible drainage paths of drilling fluids from the dome drill site at Novarupta Dome are the following:

  - The water drains from or near the top of the Naknek siltstone into numerous fresh water springs in lower Knife Creek at the contact with overlying ash-flow tuff;

  - The water drains into either the upper Knife Creek or River Lethe systems from within the deposits from 1912 and perhaps along the contact of these deposits and the Naknek siltstone. Seeps in the ash-flow sheet are observed along Knife Creek and may exist along the River Lethe.

  - At certain depths in the vent, the water at the vent drill site percolates into the hydrothermal system rather than the fresh water systems because the Naknek siltstone was breached.

• <u>Possible Drainage Paths for the Ash-Flow Drill Site</u> Drainage paths near the River Lethe are the following:

GTKat-19-1

Figure 5-4. Upper End of the Large Midvalley Thermal Springs (Left) and Approximately 130 m from the Upper End of the Springs (Right)

- The water drains directly into the river through fractures and welded layers of the ash flow and at the contact between these deposits from 1912 and the Naknek siltstone.

- The water drains into the midvalley fresh water springs through the ash-flow deposits from 1912, and along the contacts of these deposits with the Naknek siltstone.

• <u>Thermal Water Chemistry</u> Because thermal water chemistry is constant rat the midvalley thermal springs, it appears that mixing does not occur after leaving the heating zone. Simple mixing models do not account totally for the seasonal variation in temperature. The data available indicates a more complex hydrological and thermal regime. Recent chloride flux data (Keith and Ingebristen, 1991) strongly suggest additional thermal springs not only in the Knife Creek river system, but to a lesser degree, in the River Lethe system also. Moreover, the hydrothermal alteration process associated with volcanism in the Valley of Ten Thousand Smokes results in the following situations:

  - The waters of the Valley of Ten Thousand Smokes have a different water chemistry than water systems not effected by these alteration processes (shown in Appendix C).

  - The presence of ions from common drilling salts would be totally masked by natural production of these ions (inferred from arguments in Appendix C).

  - More common ions from unlikely, inadvertent production of hydrothermal waters while drilling (~50,000 gal per day for a few days) would also be masked by the natural production of these ions (inferred from arguments in Appendix C).

In the region of the vent (Novarupta Dome) the vent structure itself with the interface of the impermeable Naknek siltstone may have formed a partial hydrologic barrier that is local to the Novarupta Dome region. The 1912 eruption breached the Naknek Formation. Thus Naknek siltstone may have formed an approximately 3,300-ft (~1,000 m) cylindrical barrier around the vent at 500 ft (~150 m) or deeper.

In 1991 samples from Knife Creek, the River Lethe, the Ukak River, and fresh water springs were tested for the baseline of elements considered to be priority pollutants under the Clean Water Act, 40 CFR 423. These were tested under EPA protocol and results are provided in Appendix C. Later that year additional water samples were taken from a fresh water spring near the proposed old waterline terminus at Knife Creek, the midvalley thermal springs, snow melt from the dome, Lake Mageik, and the River Lethe at the ash-flow site. These data also were analyzed under EPA protocol and are included in Appendix A. These particular data also contain analyses of the elements that Keith has studied and in general fall within the ranges of the data in Table 5-3.

5.4 Summary of Project-Sponsored Surface Geology Studies Around Novarupta Dome and in the Valley of Ten Thousand Smokes

5.4.1 Overview of Work

A coordinated set of surface geophysical investigations was conducted in the Novarupta Dome region and elsewhere in the Valley of Ten Thousand Smokes in 1989 and 1990. This ICG-sponsored work was a significant scientific accomplishment in itself and is a portion of the integrated surface and (proposed) subsurface coring study of the 1912 event. While conditions at depth are largely unknown, these results provide an unprecedented glimpse at both surface and subsurface conditions and are integrated into the drilling plans as far as possible. The consortium of scientists were from universities, the USGS, and national laboratories. Major studies included the following:

J. W. Kleinman and E. Y. Iwatsubo (1991) set up a geodetic network to measure deformation in the Novarupta Dome area.

A. M. Goodliffe et al. (1991) performed gravity and magnetic measurements to study subsurface features.

P. Kasameyer et al. (1991) performed electromagnetic measurements to study subsurface features.

S. Ballard et al., (1991) conducted shallow heat flow measurements to study subsurface features.

J. Kienle (1991) reinterpreted earlier seismic and gravity data that were taken in the area to obtain more data on subsurface features.

P. L. Ward et al. (1991) provided interpretations on subsurface features from their established seismic network in the area.

W. Hildreth (1991) accomplished detailed field work studying 1912 ejecta in the vicinity of Mt. Katmai related to caldera collapse of Mt. Katmai with withdrawal of magma toward Novarupta and the eruption at Novarupta.

J. J. Papike et al. (1991) conducted detailed geochemical analysis of fossil fumerole encrustations to deduce chemical losses and gains and mineralogical evolution of fumaroles.

T. E. C. Keith (1991) studied alteration in the Novarupta vent region by geochemical and mineralogical analyses of rock samples.

R. P. Lowell and T. E. C. Keith (1991) considered chemical and thermal constraints of models describing the data from the midvalley thermal springs.

C. K. Shearer et al. (1991) analyzed pyroxenes and inferred magmatic evolution.

H. R. Westrich et al. (1991) studied inclusions and matrix glasses to infer pre- and posteruptive volatile contents of Katmai magmas.

J. B. Lowenstern et al. (1991) studied a sill complex near the Valley of Ten Thousand Smokes to infer the magma transport of the Novarupta vent system.

5.4.2 Results

Goodliffe et al. (1991) show that there is indeed support for the geologically-based vent-funnel hypothesis in geophysical observations. A magnetic anomaly coincides with the fractured region and, together with the gravity data, suggest twin intrusions, one coinciding with the inner vent beneath Novarupta Dome and one concealed beneath the Turtle, both within the outer vent funnel. Wallmann and Pollard (1991) also argue for a shallow intrusion under the turtle, but on the basis of surface morphology and structural considerations. Elsewhere, Wallmann et al. (1990) contend that the vent fractures and structures arise from early postemplacement slumping of tephra on steep slopes, from differential welding of vent fill, and, most significantly, from extension and deformation of welding tephra across the gently sloping, flared east and west walls of the buried vent funnel. Kasameyer et al. (1991) delineate zones of varying electrical conductivity, finding evidence of a water table at 60- to 100-m depth within much of the vent region, for conductive alteration zones beneath the tephra ring, and under the northern part of the vent area, for the Naknek bedrock funnel wall sloping toward Novarupta. Kleinman and Iwatsubo (1991) describe the vent geodetic net and report no measurable deformation after the first year of replicated measurements.

Although vigorous fumarolic activity died out within two decades of the eruption, areas of hot ground and weak steam vents persist today. From heat flow data, Ballard et al. (1991) show that most of the shallow portion of the vent is cold, and argue for the heating and localized ascent of groundwater along a still-hot feeder dike or conduit that is much smaller than the vent basin. Lowell and Keith (1991) present evidence that the ash-flow outflow sheet also locally retains some heat at depth. A still-cooling zone in the upper Lethe River valley modestly heats groundwater that emerges midvalley in several gorge-wall springs. Kienle (1991) reinterprets 20-yr-old seismic data in accord with the earlier geomorphic reasoning of Curtis (1968) to show that the ash-flow sheet approaches a maximum depth of approximately 200 m, an ample thickness to retain some heat after 79 years.

Geochemical investigations encompass preeruptive, eruptive, and post-emplacement processes. Lowenstern and Mahood (1991) consider the rare but rapid generation of high-silica rhyolite in the Aleutian arc and contend that the magma is generated in Aleutian andesite/dacite systems by coupled fractionation/upper crustal assimilation. Shearer et al. (1991) describe trace-element behavior in pyroxene/glass suggestive of replenishment events in the parent magma reservoir. By independent methods, Westrich et al. (1991) and Lowenstern (1990) obtained a preeruptive H_2O content of 4 wt% for rhyolite magma. This implies explosive fragmentation of rising magma at approximately 500-m depth, consistent with geologic evidence that the vent was excavated within the upper kilometer. Westrich et al. (1991) also report substantial

preeruptive Cl and F, but only limited loss during the eruption, indicating that these halogens were available in abundance for vapor transport of metal during high-temperature devitrification of the ash-flow sheet. Papike et al. (1991) characterize chemical transport in valley-floor fumaroles in the ash-flow sheet, arguing that much of it took place very early in the evolution of these systems. Keith (1991) describes active fracture-controlled argillic alteration in the vent region and its chemical history.

Aspects of the deep magmatic plumbing of the Katmai system have also been studied. Lateral connectedness of the magma system that gave rise to the 1912 eruption is demonstrated by Hildreth's (1991) discovery that collapse of Mt. Katmai began within hours of the onset of the eruption at Novarupta. Wallmann et al. (1990) presented the case for magma propagating in a dike or dikes toward Novarupta from beneath Trident and not directly from Mt. Katmai. Lowenstern et al. (1991) offer a possible exit from this dilemma, using a fossil analog to suggest a sill-like connection between Katmai and Trident. Ward et al. (1991) do indeed find evidence for magma beneath the Trident Volcano and Katmai Pass area, perhaps the main source chamber for the 1912 eruption and a source for the 1953 to 1963 Trident eruption, though the latter lavas are not simply 1912 leftovers [Hildreth, 1987].

6.0 DRILLING OBJECTIVES, TECHNICAL APPROACH, AND EXPECTED RESULTS

The results of the Katmai project will provide an in-depth understanding of one of the most interesting volcanic features of the Earth, and certainly, of Katmai National Park: the Novarupta vent. The Novarupta vent is a unique volcanic site (NAS, 1989); the size, youth, elevated temperature, and simplicity of the Novarupta vent make understanding its internal structure and conditions an important scientific objective.

Size

The Katmai eruption was the Earth's largest rhyolitic event in the last 1,800 years and the only historic eruption to produce a welded tuff sheet. Although 1/10 to 1/100 the size of the largest eruptions that have occurred on the earth, the Katmai event is of a class of eruptions that was both large enough to be catastrophic in impact and frequent enough to represent a serious threat to human activities. Its great size contributed to retention of significant heat at shallow depth and, undoubtedly, to much posteruptive metal migration.

Youth

Because the eruption is so recent, eyewitness accounts provide information on the timing of the eruption. The damage to deposits by erosion and weathering is minimal. Most importantly, because of the age and size of the system, the surface is cool while elevated and possibly high temperatures persist within the upper 0.6 mi (1 km). Thus at this location the cooling of an igneous intrusion can be directly observed for the first time. The short time since emplacement also minimizes chemical alteration of rare, less resistant minerals and glasses.

Simplicity

The 1912 eruption was a single eruption of magma passing through uniform sedimentary bedrock at a site where little previous volcanic activity (none rhyolitic) had occurred. Therefore, temperature, chemical, and structural observations at depth can be directly related to the 1912 event. In addition, the remarkable 6-mi (10-km) separation between the eruption site and the site where collapse, due to the subsurface withdrawal of magma, took place uniquely permitted preservation of the vent structure.

The following are the primary scientific objectives for the Katmai project. Attaining these objectives will contribute to a greater understanding of silicic igneous activity.

6.1 Objective 1

6.1.1 Describe the Physical and Chemical Behavior of Magma and Its Host Rock During Intrusion and Eruption

The rapid flow of a large volume of thick, viscous magma upward through the rocks comprising the Earth's crust is a complex mechanical process. Aspects of the process include fracturing of bedrock by magma; flow of magma;

growth of bubbles; expansion and breakup of the magma to ash, pumice, and gas; and excavation of the vent. This process can be divided into the behavior of magma and the behavior of the conduit system. The project will test existing theories concerning intrusion and eruption processes and geologic concepts of vent geometry and development.

6.1.2 Approach to Objective 1

Models for molten rock behavior during intrusion and eruption depend first on the size and geometry of the system. Results from the continuous core sections of the drill core holes will provide a subsurface view of vent structure. Drilling results will be combined with surface geological and geophysical observations to develop a fully consistent geometrical model of the vent. A complete section of core through the ash-flow sheet, together with surface geologic observations, will show the sequence in which the eruption deposits formed. Matching these deposits with equivalent layers encountered by drilling inside the vent will show the growth of the vent over time. The timing of the vent's periods of constriction, collapse, and intrusion can also be determined. The nature of the excavation of the vent can be determined by the basement fragment distribution in the vent-fill and the ash-flow sheet. The extent that the vent was formed by collapse of wall rock into magma (rather than by excavation of wall rock by erupting magma) can be determined by the identification of down-dropped blocks of basement relative to vent volume.

Glassy rocks in the vent representing magma that cooled too quickly to grow crystals will be analyzed for chemically bound gases. This will show how the gases in the magma changed as the magma approached the surface and pressure decreased. The amount and composition of gases contained in the glass will indicate the source(s) of the gases, which would be either from the interior of the Earth or the atmosphere. The core will also be studied to map glass-rich (quickly cooled) and crystal-rich (slowly cooled) zones. This will show how the magma solidified as it lost heat and gas. Zones of alteration will also be studied because these reflect prolonged exposure to circulating hot water. The relative timing of crystallization and alteration events both before and after 1912 will be determined by radiometric dating.

Results of these investigations should identify the processes which occur during an explosive eruption and the processes which control whether an eruption will be explosive and ash-forming, or nonexplosive and lava-forming.

6.2 Objective 2

6.2.1 Determine the Source, Mechanism, and Conditions of Metals Transport

The transport of metals includes identification of the source(s) of metals, the cause and timing of release, the origin of the transporting vapors, and the identification of conditions such as temperature, pressure, and gas composition-controlling transport rates. Possible metal sources are unerupted magma, country (host) rock, or ash. Transporting vapors may have originated from erupted material or from snow and streams buried by the eruption. Comparison of metals transport in the environments of the ash-flow sheet and the vent may be especially important. Conditions differed sub-

stantially between the ash-flow sheet, which is flat and composed of individual ash particles and pumice fragments, and the vent, which is chimney-like and may contain a significant proportion of intact igneous rock (Figure 6-1).

The conditions and mechanisms of metals migration will be determined by the subsurface mapping of metals enrichment and depletion zones, the spatial relationship of these zones, and their isotopic character. As shown in Figure 6-1, metals mobilization occurs during crystallization, though other possibilities exist. Steam of magmatic or atmospheric origin transports the metals. Note that magmatic vapor may dominate in the chimney-like vent, while an influx of atmospheric water may be more important in the slab-like ash-flow sheet.

6.2.2 Approach to Objective 2

The approach to objective 2 is to describe the distribution of metals in the igneous host rock system and to interpret the means by which portions of the system reach their present chemical state.

For the igneous portion of the system, initial metal concentrations in the magma prior to eruption will be estimated by the analysis of glass inclusions from each of the three magma types. The inclusions represent samples of liquid rock encapsulated in crystals prior to eruption and therefore protected from the reduction in pressure that caused the magma to lose gas and metals. Metals concentrations in the magma immediately following eruption will be obtained by analyzing a complete collection of quenched pumices. These baseline values will then be compared with observations from the multiple continuous core sections of the intrusive and eruptive portions of the system. Enrichment and depletion zones of metals will be mapped. The relationship of the metals-depleted and metals-enriched volumes to crystallization zones, specific magma types, fluid entry, and gas flow will be determined. These observations will be interpreted in terms of the effects of decompression (pressure reduction) during eruption and crystallization during the cooling of metals.

Similarly, metals concentrations along profiles into the vent wall and into the valley floor beneath the ash-flow sheet will be obtained. These observations will be analyzed to describe the interaction of the host rock with magmatic gas and magmatically heated water. Conditions and mechanisms of metals transport will be deduced from considerations of the mineralogy of fumarolic deposits and analysis of fluid inclusions in crystals deposited by fumaroles. Results will indicate the chemical and physical conditions controlling metals transport and will lead to conclusions about the cause of metals transport during some eruptions but not during others. These investigations will also aid in the interpretation of the processes responsible for the formation and preservation of volcanic-rock-hosted ore deposits.

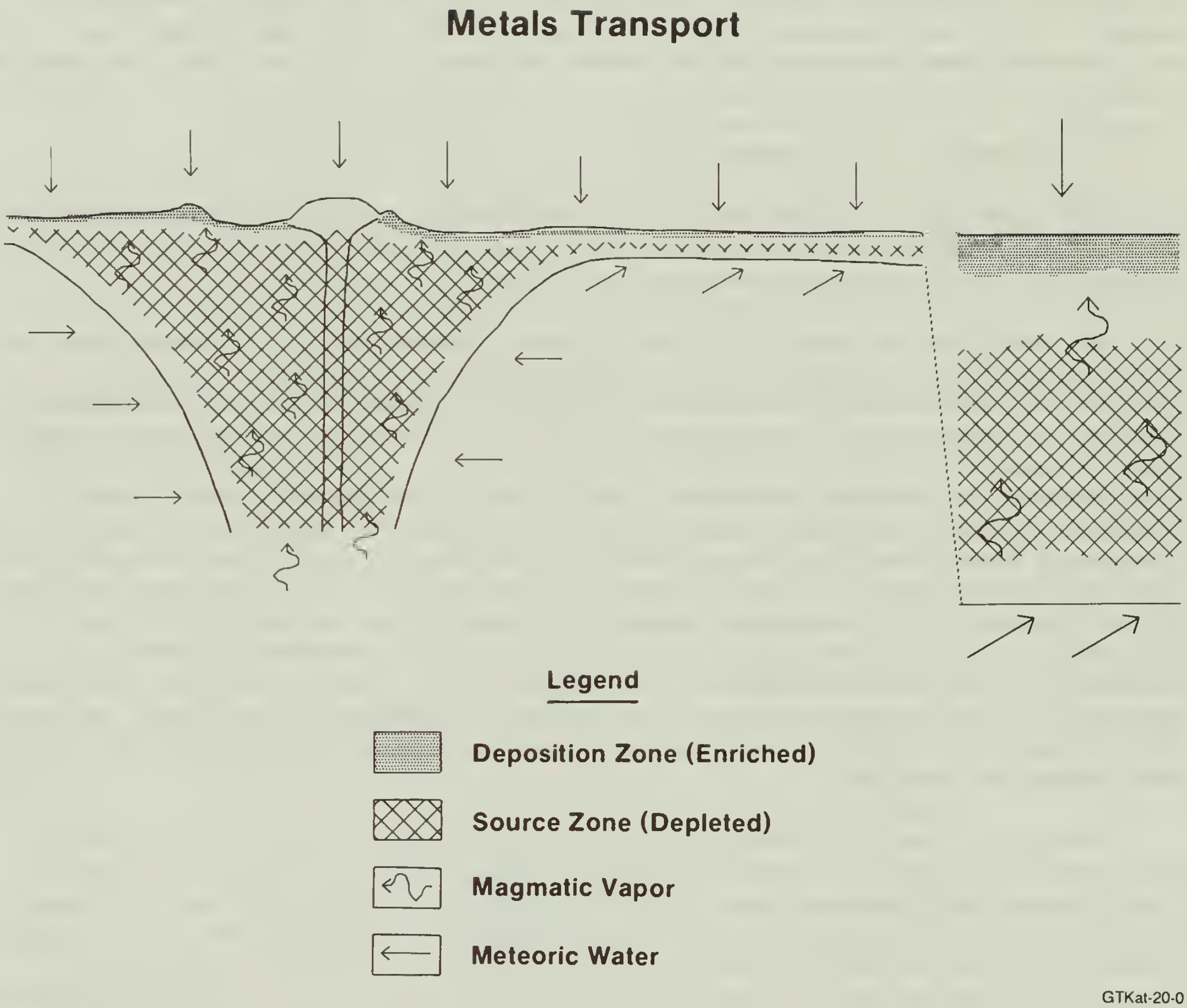

Figure 6-1. Schematic of Metals Transport

6.3 Objective 3

6.3.1 Measure the Current Subsurface Temperature Distribution and Test Models for the Cooling of Igneous Systems

Models predicting the rates and ways by which igneous intrusions cool and undergo changes in mineralogy as a result of cooling have not been tested by observation of actual cooling systems. The vent for the eruption in 1912 and its contained intrusions are unquestionably still cooling. In theory, the system has passed from molten conditions, through a very hot vapor stage when there were newly crystallized rock and steam in the vent, to a moderate-to-low temperature hydrothermal stage when hot water began circulating and altering the rocks to clay. Portions of the vent and conduit could have remained in the vapor stage and could still contain magma. Drilling into a simple, still-cooling system at a known point in time after its formation will provide fundamentally new information, such as the speed that heat travels in the Earth's crust and the rate at which rocks change their composition. This is a rare opportunity to determine the rates of major geologic processes.

6.3.2 Approach to Objective 3

The Katmai project will observe and sample an active hydrothermal system 80 yr after its formation. This is very young geologically. Magmatic temperatures of ejecta from 1912 have been deduced from mineral data (Hildreth, 1983), and these values can be used to estimate temperatures in and near the vent when it first formed. The present temperature conditions will be described by determining the surface heat flow and by measuring the temperatures in boreholes (Chapter 8.0). Zones of conduction (where heat flows through rock) and convection (where heat is carried by flowing water) will be identified. The relative timing of crystallization and alteration events will provide further information about the posteruption history.

This first measurement of the rate at which an igneous intrusion has cooled will show the accuracy of present mathematical models for heat flow in the Earth's crust. Results will be applicable to the predicted behavior of repositories for the isolation of radioactive waste, as well as for understanding volcanism. In general, volcanoes are repeatedly intruded by pulses of magma. Results of the Katmai project should permit an assessment of the extent to which heat from one eruption may influence the course of successive eruptions.

6.4 Expected Results

The Katmai Drilling Project will provide the following:

- Improved knowledge of how explosive eruptions occur.
- Improved knowledge of the release of gases, including toxic gases, during volcanic activity.
- Improved knowledge of how geothermal systems (underground steam) form and evolve.

- Improved knowledge of how metallic ore deposits form.
- Improved knowledge of how magma (molten rock), heat, and fluids move through the Earth's Crust.
- Addition of the third dimension to the Park's Interpretive Program: A detailed description of volcanoes as the top of huge and powerful magma systems within the Earth.

7.0 WELL DESIGN AND CONSIDERATION OF DRILLING RIGS

A well design is provided on the basis of available data. Schematics for the 4,000-ft (~1,200-m) vertical hole, the beginning of the 3,000-ft (1,000 m) deviated hole, and the 650-ft (~200-m) slant hole are shown in Figures 7-1 and 7-2, respectively. Well designs are consistent with 36 CFR 9(B) and the State of Alaska Geothermal Drilling Regulations. The project will request two specific variances to the state geothermal regulations, which are discussed in Sections 8.4 and 8.7.

Top-to-bottom core is desired; thus, diamond core drilling is planned. In diamond core drilling, the core is lifted on a wireline; hence, there is the very significant advantage of not having to remove the drill string for core removal. These diamond core rigs are typically approximately one-third the size of a rotary drilling rig specified to the same depth that would be used in hydrocarbon extraction. The diamond core holes are smaller in diameter by a factor of two to four over core holes drilled with rotary rigs. The drilling fluid systems for diamond core operations are also much smaller than those for rotary rigs because circulation rates are lower by roughly an order of magnitude. Thus, the smaller, lighter diamond core systems are superior for many uses in both remote and environmentally sensitive areas. Such a system is planned for this proposed Katmai project.

Drilling and coring in volcanic rock at high temperature is well established. Work of this nature has occurred for almost a decade (Deliac et al., 1991). This is an accepted way of determining temperature gradients in a geothermal reservoir.

Actually, elements of two separate industries are involved: minerals coring and oil field drilling. This project will combine aspects of both industries in the use of a minerals (wireline coring) rig to take core and the use of oil field technology to set up blowout prevention. The construction of a substructure to mount the diamond core rig allows adequate room for the blow out preventer system (stack) and, at the same time, avoids a cellar where hydrogen sulfice gas could accumulate.

Rigs at both sites will be mounted on a substructure. Figure 7-3 shows a Universal 1500 Drill Rig mounted on a substructure. (Substructure height 9 feet, mast height 53 feet, additional. Length, excluding core laydown, is approximately 37 feet, width is approximately 12 feet). The truck mount, shown in the figure <u>is not appropriate to this proposed project</u>. Any rig to be used must be flown in. Assembly of the major components of the rig would be with the aid of the helicopter.

Because drilling conditions are expected to be difficult, the diamond core rig chosen for this project will be one of the more powerful rigs that is transportable by helicopter. The rig assembly will also include a drill frame and a derrick. Tools and spare parts will be included (Section 8.1). Examples of rigs under consideration for the dome site are a Longyear Super Hydro 44, Chicago Pneumatic 50, J. K. S. Boyles B30H, or a Universal 1500 rig. Examples of rigs under consideration for the ash-flow site are a Longyear 38 and a Diversified Machine Works Inc. 65 Drill.

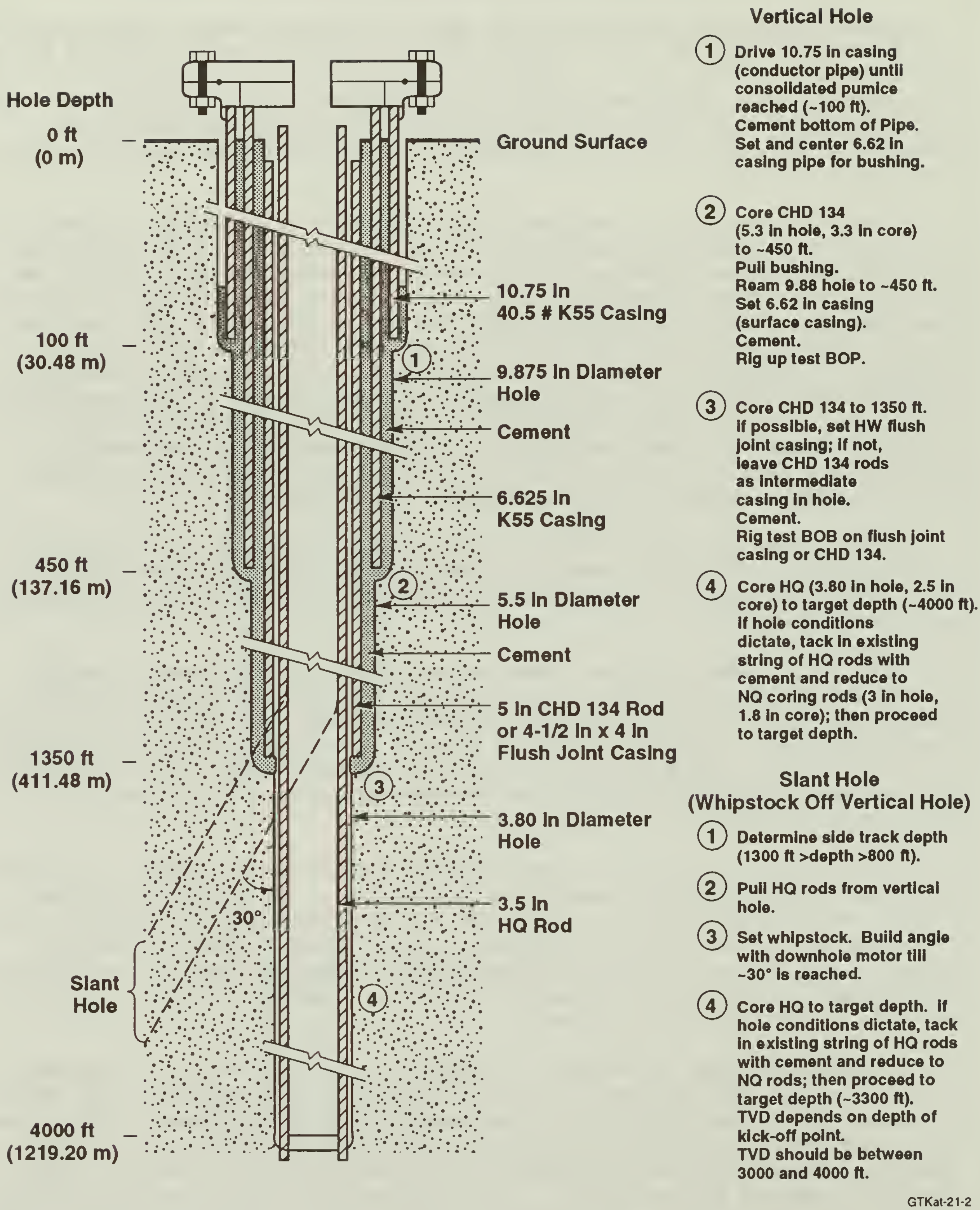

Figure 7-1. Design of Core Holes at the Dome Site

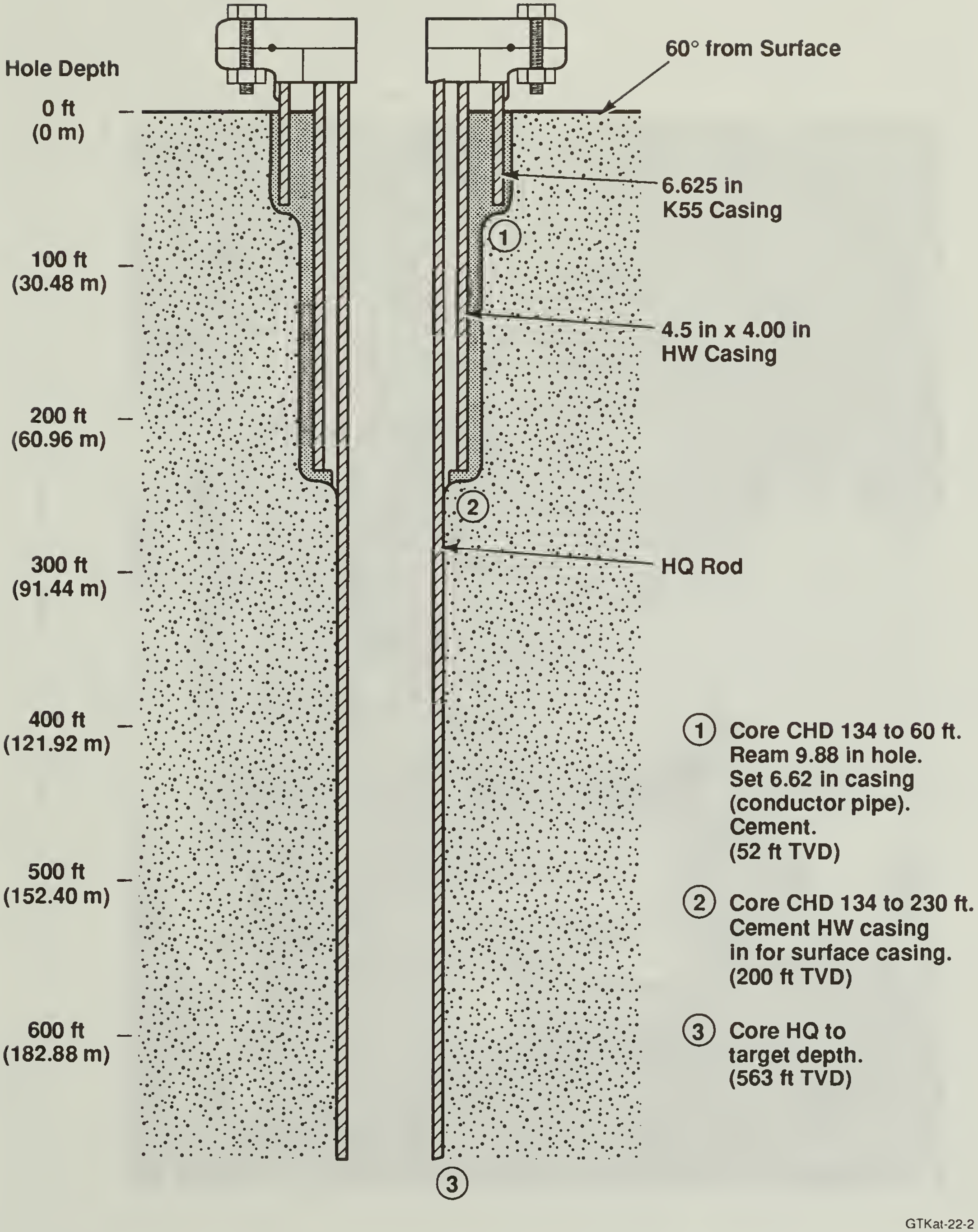

Figure 7-2. Design of the Core Hole at the Ash-Flow Site

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Figure 7-3. Universal 1500 Drill Rig Mounted on a Substructure (Truck Mount Not Appropriate to This Project)

The 4,000-ft vertical hole and the 3,300-ft slant hole will be cored through the same drill pad and casing string (Figure 7-1). The vertical hole will be completed first. If drilling conditions are good, the HQ rods of the vertical hole will be pulled and a permanent whipstock will be placed in the casing between 800 to 1,300 ft (~250 and 400 m) below the surface. The hole will be sidetracked off the whipstock and a window will be milled out of the casing. A special drilling assembly with a downhole motor will be employed to continue to build the angle gradually until the described 60-degree slant angle is reached. Then coring will commence underneath the dome.

The tubulars for the vertical hole at the dome drill pad will consist of the following:

- a K55 casing conductor pipe (10 3/4 in., 40 lb/ft) through loose pumice into more consolidated rock to approximately 100 ft (~33 m);
- a K55 surface casing pipe (6 5/8 in., 24 lb/ft) to approximately 450 ft (~140 m);
- CHD 134 coring rod as intermediate casing (5 in. o.d., 4 1/2 in. i.d., 14.3 lb/ft) or flush joint casing (4 1/2 in. o.d., 4 in. i.d., 11.3 lb/ft) to approximately 1,350 ft (~400 m);
- HQ coring rod (3 1/2 in. o.d., 3 1/16 in. i.d., 10.6 lb/ft) to approximately 4,000 ft (~1,200 m); and
- if problems arise that necessitate a smaller coring rod, continue with NQ coring rod (2 3/4 in. o.d., 2 3/8 in. i.d., 7.7 lb/ft) to approximately 4,000 ft (to be used if HQ rods are set above the target depth).

The coring rod in the deviated hole at the dome drill site will be HQ to the target depth of 3,300 ft (~1,000 m). If problems arise in the deviated hole, NQ coring rods will be employed.

The slant hole at the ash-flow site will have the following tubulars (Figure 7-2):

- 6 7/8-in. casing and conductor pipe to approximately 60 ft (~18 m);
- CHD 134 coring rods (casing) to approximately 230 ft (~70 m); and
- HQ coring rods to approximately 650 ft (~200 m).

The method of diamond core drilling allows the nesting of one set of coring rods within a larger set of rods. For example, 3.5-in. HQ rods will be nested within the 5-in. CHD 134 rods (Figure 7.1). Use of the H coring rod allows, in turn, the option of further necking down to a smaller coring rod in certain situations, such as sticking the coring rods. Another situation when necking down may be used would be when it is desirable to stop and cement in the coring rods in the hole to enhance well control by advancing the casing point (Section 10.2). Although necking down may not be necessary, using the 3.5-in. O.D. H coring rod allows necking down to the 2.75-in. N rod. In

principle, one could neck down further to the 2.19 in. B rod. Core samples would become correspondingly smaller; however, this procedure allows the option to safely advance the core hole further under certain conditions.

Blowout prevention equipment will be in accordance with NPS regulations and the State of Alaska Geothermal Regulations. This will include a double gate with both blind and pipe rams, and a Hydrill bag at the dome site. All core holes will have a rotating head assembly. (A Hydrill bag and a mechanical gate value may be sufficient for the slant hole at the ash-flow site.)

The wellhead design will be consistent with State of Alaska Geothermal Drilling Regulations and 36 CFR 9(B). The wellhead will be welded to the main casing string, will be rated to 2,000 psi, and will have a 4-in. full opening valve. The choke and kill lines below the wellhead can be valved off.

8.0 DRILLING OPERATIONS

8.1 Drill Sites, Equipment, and Waterlines

There will be two drill sites. A 4,000-ft vertical hole and a 3,300-ft slant hole will be drilled at the main drill site next to Novarupta Dome (Section 4.3). The main drill site and the campsite will be located adjacent to each other within Novarupta Dome. A less extensive 650-ft slant hole will be drilled at an ash-flow site in the Valley of Ten Thousand Smokes, which is approximately 3 mi from Novarupta Dome near the River Lethe. Both drill sites will be located in actively alluviating areas; therefore, no primary eruption features will be disturbed and the vegetation in these areas is generally sparse and subject to natural burial (see Section 4.1).

The drill site at Novarupta Dome will occupy approximately 1.9 acres (Figure 4-10). All elements of both drill sites are aboveground. Tanks, bladders, or drums (no pits) will be used for storage of drilling water and returned drilling fluids. Excavation will be necessary to construct bermed areas that are mainly for the storage of sensitive fluids. Table 8-1 describes the dome drill site equipment and areas within the drill site and their functions. The drill site and campsite share power, fuel, office space, and the helicopter pad.

The ash-fall drill site will occupy approximately 1.0 acre. This site contains the same type of equipment used at the drill site at Novarupta Dome, but on a smaller scale (Figure 4-11). The remote site will also have a combination survival tent/office, as well as a restroom facility. Tanks, bladders, or drums (no pits) will be used for drilling water and returned drilling fluids. Excavation will be necessary to construct bermed areas to store sensitive fluids. Table 8-2 describes the ash-fall site equipment and areas within the site and their functions.

A waterline consisting of parallel insulated aluminum (or plastic) lines that are 2 in. in diameter will be run between the main dome site and Mageik Lake (Figures 8-1 and 8-2). Due to the approximate 500-ft elevation difference between Mageik Lake and the top of the tephra ring and due to potential heating requirements, as many as five booster stations may be necessary. These stations will be at Mageik Lake, just outside the tephra ring, and spaced equally within the outer two stations. The booster stations will also contain provisions for heating water to prevent the line from freezing. During warm weather, as few as three of these stations will be operational. The booster station will consist of a booster pump, a surge tank with an approximate 300-gal capacity, and a heating unit. The entire unit will be skid-mounted. The skid will be approximately 12 ft long, 6 ft wide, and 4 ft high. A small amount of fuel to power the booster station will be in a berm, or in a container that is environmentally equivalent. The waterline will be checked by helicopter, and on foot by walking adjacent to the waterline. (The waterline between the River Lethe and ash-flow site will be approximately 200 ft long and will be simple to lay and maintain.)

Table 8-1

Description of Areas and Equipment at the Novarupta Dome Site

Equipment or Area	Function
Helicopter pad	For helicopter landings
Mechanics shed	Workshed of the helicopter and rig mechanics
Office (part of the nearby camp)	Used as a base for project management and as a communications center for operations
Fuel storage area	Consists of a bermed, lined area for storing fuel to power drilling and camp operations
Generator sets	Provide power to the drill site and camp. There will be backup to compensate for generator maintenance and failure.
Drill pad	Provides a stable base for the substructure and rig. Constructed of interlocking timbers.
Rig	Drills the core holes
Rig substructure	Provides mounting for the rig on the drill pad and the blowout prevention system
Core lay-down area	Area to lay down the wireline core barrel to extract the core
Core facility (located within or nearby the campsite)	Facility to process and log the core, which is performed by the PIs and the Curation Office (CO)
Extra rod storage, equipment rack	Area to store the tubulars
Parts shed	Storage of spare parts for the rig, as well as other site equipment
Utility corridors	Corridors to run power cables, waterlines, etc. Fuel lines in these corridors will have absorbent pads over all elbows and joints.
Water storage tanks	Store water for drilling, well control, and well safety
Fluid additive shed	Storage of solid drilling fluid additives
Drilling fluid makeup	Area where drilling fluid additives are mixed. The drilling fluid pump will be located in this area.

Table 8-1 (Concluded)

Description of Areas and Equipment at the Novarupta Dome site

Equipment or Area	Function
Drilling fluid return	Storage of returned drilling fluids. Fluids will be sent to drilling fluid treatment or may go directly back to fluid makeup.
Drilling fluid treatment	Area where solids removed from the drilling fluid stream are treated and sent either to drilling fluid makeup or to surface discharge
Surface discharge drain field	Discharge of treated drilling fluid into the ground
Spoils pile	Storage of solid material removed from the drilling fluid stream in a mobile hopper; area to be lined
Cuttings storage	Cuttings from dewatering operation are stored for use as lost circulation material or for removal out of the park
Cementing equipment	Used to cement tubulars in the drill holes to the formation
Cement materials	Area for storage of cement materials
Compressor	Provides compressed air to site operations
Logging skid	Contains equipment for wellbore measurements
Incinerator	Burns combustible waste
Toilet	Either electric- or propane-fired

Table 8-2

Description of Areas and Equipment at the Ash-Flow Site

Equipment or Area	Function
Helicopter pad	For helicopter landings
Office/survival tent	Used as a base for operations management at the ash-fall site. The office/survival tent provides shelter and a sleeping area when weather precludes relief of crew by helicopter. Also, it will be used as a food cache, with stove, etc. Some processing of core may also be performed in this area.
Fuel storage area	Consists of a bermed, lined area for storing fuel to power drilling and camp operations
Generator	Provides power to the drill site and camp
Drill pad	Provides a stable base for the substructure and rig. Constructed of interlocking timbers.
Drill rig	Drills the core hole
Rig substructure	Provides mounting for the rig on the drill pad and blowout prevention system
Core lay-down area/ Extra rod storage area	Area to let down the wireline core barrel to extract the core and also the area to store tubulars
Parts shed	Storage of spare parts for the rig, as well as other site equipment
Utility corridors	Corridors to run powers cables, waterlines, and etc. Fuel lines in these corridors will have absorbent pads over all elbows and joints.
Water storage tank	Stores water for drilling, well control, and well safety
Fluid additive shed	Storage of solid drilling fluid additives
Drilling fluid makeup	Area where drilling fluid additives are mixed. The drilling fluid pump will be located in this area.

Table 8-2 (Concluded)

Description of Areas and Equipment at the Ash-Flow site

Equipment or Area	Function
Drilling fluid return	Storage or returned drilling fluids. Fluids will be sent to drilling fluid treatment or may go back directly to fluid makeup.
Drilling fluid treatment	Area where solids are removed from the drilling fluid stream. Drilling fluids are treated and sent to drilling fluid makeup.
Spoils pile	Storage of solid material removed from the drilling fluid stream in a mobile hopper. This area will be lined. The stored material will be used for injection during periods of lost circulation or flown to the cutting storage at the dome site.
Cementing equipment	Used to cement tubulars in the core hole to the formation
Cement materials	Area for storage of cement materials
Compressor	Provides compressed air to site operations
Logging skid	Contains equipment for wellcore measurements
Toilet	Either electric- or propane-fired

Water Source

Mageik Lake is the best water source, based on source reliability, terrain, and relative ease of maintainance. The River Lethe is close to the ash-flow site.

An alternative water source for the waterline is the River Lethe (Figure 8-1). Water flow of the River Lethe near the ash-flow site has been observed from mid-June to early July. However, water flow from this source before early-July is not always reliable. The route for the alternative water source has not been surveyed. Filtration would be necessary to make this River Lethe water potable, and filtration may be necessary for drilling.

A decision was made to choose a waterline option for the drilling water source rather than to drill for water within the tephra ring to support the operation. There is no guarantee that water would be found in such a well.

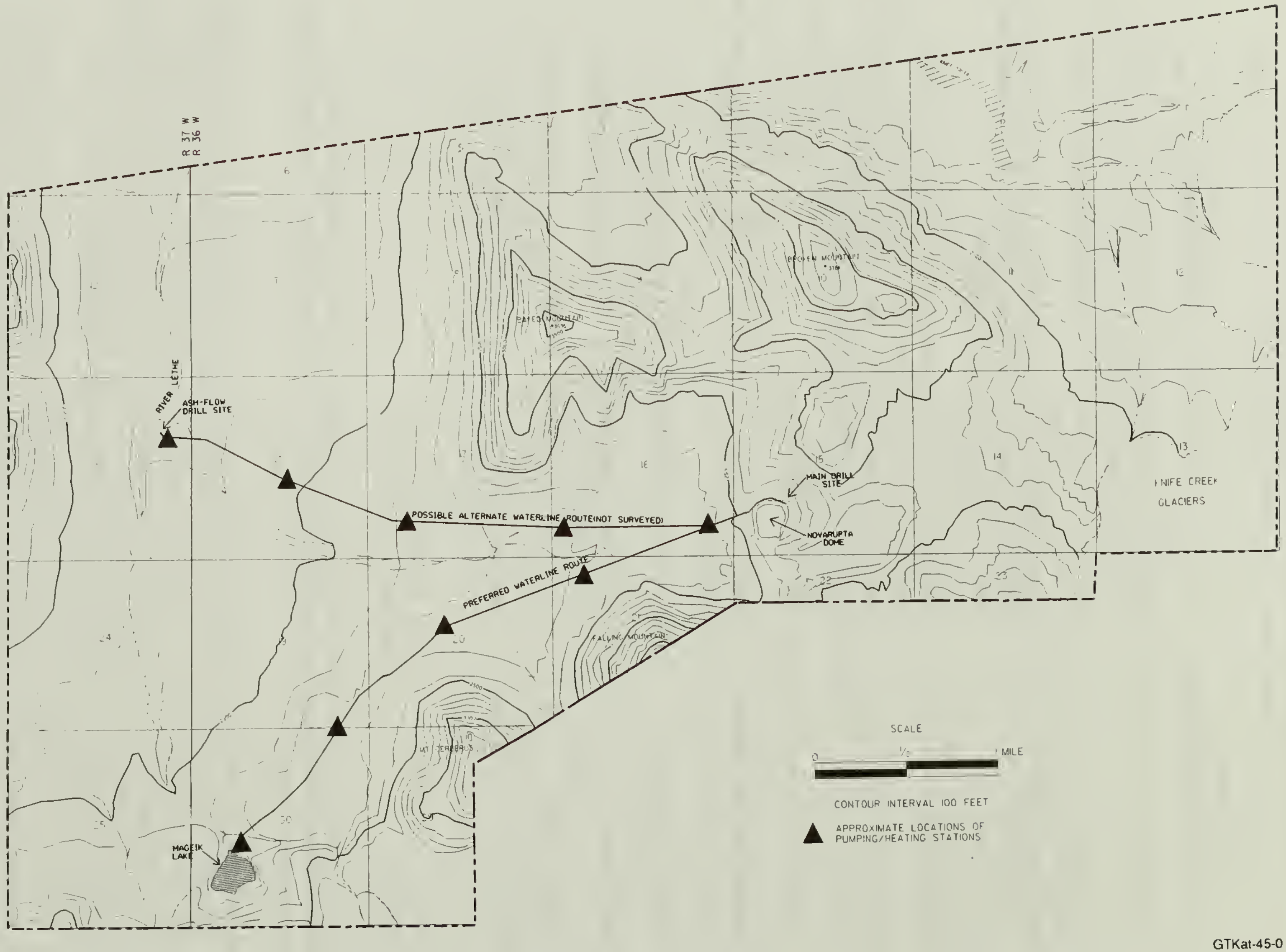


Figure 8-1. Primary and Alternate Waterline Routes

GTKat-49-0

Figure 8-2. East Mageik Lake Viewed from Southwest

If, however, adequate amounts of useable water are found at shallow depths during the early stages of drilling at the dome site, then use of such a water well will be an option to be considered at that time. The small rig at the ash-flow site could be used to drill the nearby offset water well within the dome while maintaining progress on the vertical well.

Knife Creek was also considered a potential water source. However, the area is eroding so rapidly that it would be extremely difficult to use as a water source. The elevation difference is fairly high, (approximately 900 ft) and would necessitate a large number of booster stations. The water is full of sediment. An elaborate filtering system would be necessary. There are numerous large gullies between the dome site and the creek, making both the laying of the line and maintainance difficult and dangerous.

8.2 Schedule and Season of Operation

Katmai project operations will take place over approximately 18 months. This includes periods of intense activity during two consecutive warm seasons and a period of little-to-no activity during winter months. There will be only one major mobilization of the drill rig and most of the components for the dome site. A minor demobilization of drilling and camp equipment will occur before the intervening winter. Drilling sites and campsites will be remobilized in the second warm season. This second mobilization is also relatively minor (Chapter 11). Earlier planning of the Katmai project included a full three-stage, three-year operation with complete mobilizations and demobilizations each year. This document proposes a single-stage, split-season operation that will reduce helicopter flights into the park.

The schedule will depend on the date of a ROD favorable to the project. Moreover, the schedule of operations (Sec 3.3) is predicated on a favorable ROD in the fall of 1993. The schedule also depends on the weather. GRDO will wish to begin as soon as possible in the warm season because the weather window for general operation, specifically for waterline operation and maintenance, is narrow and can become problematic as early as September (see Sections 8.3.1 and 15.4). Estimated extreme minimum temperatures increase 25°F between May and June and drop 25°F between September and October. Thus, it would be ideal to have drilling operations begin in early June with the attendant waterline support, even if this implies some snow removal. Water for the campsite and site setup during waterline installation and before drilling commencement can either be obtained from snow melt within the tephra ring or can be flown in.

The operation will commence in mid-April 1994 when the first barge access to the Bristol Bay area is available and will continue through the warm season (Figure 8-3). The site will then be shut down and winterized until spring. The supply of onsite fuel, lubricants, and liquid drilling fluid additives will be drawn down as the winter shutdown approaches and will be transported offsite before the shutdown, if necessary. No sensitive fluids will remain onsite. Liquid items and items that cannot be stored in cold weather will be removed from the site. The drill rig, pumps, and other apparatus will be properly winterized. Winterization includes draining water from all lines, ensuring that proper lubricants remain in the various engines, and securely covering all exhaust and open ports of the engines. Solid

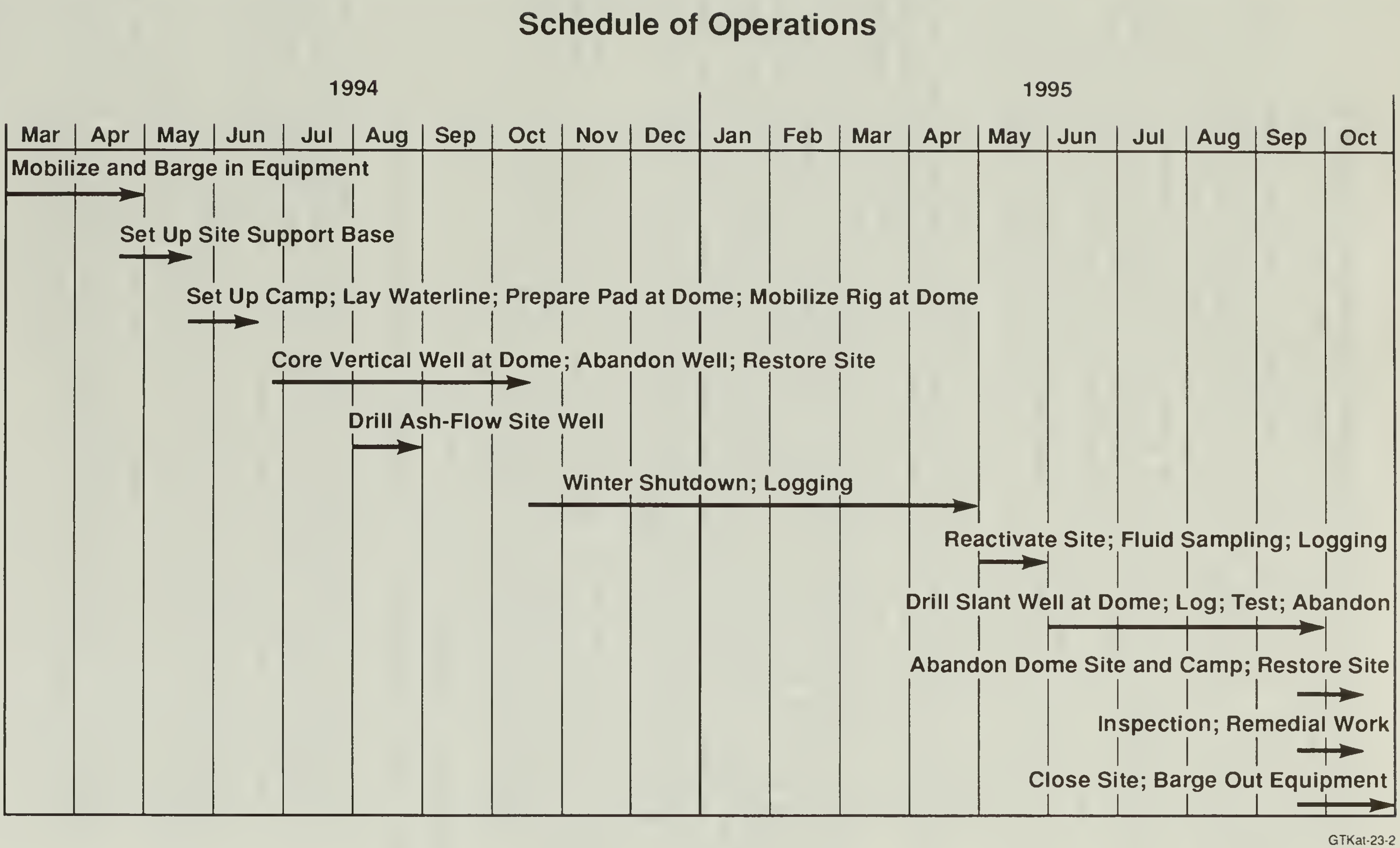


Figure 8-3. Schedule of Operations

drilling fluid additives and other similar items will be stored in weatherproof, waterproof modules or in water-tight boxes.

The vertical hole at the dome site should be concluded before winter shutdown. The hole will not be left in an open condition. Casing and HQ rods will be in place. The blowout prevention system will be removed and a wellhead will be affixed for the winter. The wellhead, like the blowout prevention system, will be welded and anchored to the intermediate casing strings (see Section 8.7). The wellhead will be anchored to all the casing strings through the cementing of the conductor and surface casing strings (and often through insertion of metal doughnuts between the various sets of tubulars). If winter conditions force termination of the vertical hole operation before the completion of the hole and hole conditions are severe, a removable bridge plug will be placed in the hole to further seal off the formation from the surface.

Site inspections to check the wellhead drilling equipment and camp will be conducted at approximately four- to six-week intervals during this shutdown period. The inspection party will consist of project personnel. Logging of the hole will take place concurrent with the site inspection. NPS or USGS personnel will probably accompany project personnel on these helicopter trips. If serious problems arise that cannot be handled by the inspection party, appropriate personnel will be helicoptered to the site to correct any problems during shutdown. Such people will be available to respond to any emergency during the winter shutdown. One alternative is to leave two caretakers to watch the wellhead, to keep snow off the camp, to remove snow at the site, etc. In this instance, the inspection flights may be more frequent and would also serve to facilitate the change of caretaker crew.

Operations will resume in spring as soon as weather permits. Operations will continue until the core holes are complete or cold weather in the fall forces the termination of the operation. Some testing (geophysical logging) and fluid sampling of the vertical hole at the dome will occur in the spring of 1995 before drilling the slant well at the dome site.

8.3 Operational Sequence

The following sequence of operations is planned.

- Enter the park by helicopter in the summer of 1992 to tie in the surveyed drill and campsites into landmarks and later to the regular quadrangle maps. Recheck the survey of the new campsite. Measure flow from Lake Mageik in the River Lethe. Dames and Moore must accomplish additional tasks associated with visual impact, wildlife, plant biology, and other cultural considerations.

- Enter the park in summer 1993 by helicopter for site inspection with the drilling and camp contractors. This will be the only look the selected contractors will have of the site before the stakeout in the fall. It is essential that contractors selected to drill and to set up the camp inspect the site before the operation.

- Before the operation itself, it would be wise to bore up to 80 ft into the loose pumice using small drill to obtain information about pumice stability, drill pad support, and drilling conditions. A small generator or compressor would be needed. Afterwards the surface area will be restored with hand tools. Pumice samples will be tested with hand tools for load-bearing capacity and will be analyzed by project scientists.

- Lay out the drill sites and campsites during the fall (1993) before fielding. The GRDO, USGS, the drilling and camp representatives, and the NPS will perform these tasks.

- Start mobilization of equipment throughout the United States and Canada early 1994.

- Load barges from Seattle, Canada, and Anchorage to Naknek. Move equipment from docks at Naknek and move equipment arriving at King Salmon by air to a support base at the King Salmon Airport late spring 1994.

- Mobilize camp and begin the limited excavation at the dome site necessary for the project. Excavation is limited primarily to construction of berms and shallow depressions for storage and containment of sensitive fluids. No deep pits will be excavated because water and fuels will be stored in surface tanks, bladders, or drums. Construct drill pad of interlocking timbers. Drill bolts into nearby boulders to secure guy wires and to secure the rig mast from the wind. (At the ash-flow site it may be necessary to pour cement into small holes into the ash flow for the guy wires.)

  A utility vehicle such as a grade-all, or a wide-track low-pressure D3 or D4 Caterpillar tractor will be used to support the operation at the dome and ash-flow sites. The vehicle will have an attachment to mount a blade for excavation, forklift, and, possibly, backhoe to support the operation. The vehicle may be used for drain field construction to contain campsite grey water.

- Lay waterline from the dome site to Lake Mageik (Figure 8-1).

- Mobilize the coring rig at the dome site in late May or early June at Novarupta Dome. Commence with drilling and coring of the 4,000-ft vertical core hole on a 24-hr basis with three persons per shift.

- Drive and rotate the conductor pipe through unconsolidated pumice and cement the bottom in place in the more consolidated rock. Examples of methods used to advance casing are utilizating a casing hammer and rotating the casing.

- Core to the surface casing depth, ream the hole, and set and cement the surface casing. Install and test the temporary blowout prevention equipment.

- Core through the cement in the surface casing, core to the intermediate casing depth, ream the hole, and set and cement the intermediate casing. Install and test the blowout prevention equipment. Complete the vertical hole.

- When the intermediate casing string and blowout prevention equipment are set at the dome site, a short waterline will be run from the River Lethe to the ash-flow site (~200 ft).

- Activate the rig at the ash-flow site on a 24-hr basis with two or three persons per shift.

- Core the hole at the ash-flow site to the conductor pipe depth. Ream the hole. Set and cement the conductor pipe. Core the hole to the surface casing depth. Ream the hole. Set and cement the surface casing. Install and test the abbreviated blowout prevention system. Complete the hole. Remove the coring rods. Set a cement plug to the bottom of the surface casing. Cut casing off below the surface, plug, and abandon the hole. Restore the ash-flow site.

  The essential equipment for the hole at the ash-flow site will be dropped off during the main mobilization. If there are delays at the dome site, this hole will be activated earlier. Equipment will be removed from this site to King Salmon no later than the minor demobilization for the winter shutdown in the first season.

- Log and process the core from both wells as it becomes available.

- Geochemically monitor solid and water samples taken from the holes, streams, and rivers to comply with regulations and directives from appropriate permitting agencies. (This is an ongoing activity while drilling and coring are in progress.)

- After an interim inspection by the NPS and the State of Alaska, winterize and shut down the dome site and supporting camp in the fall of 1994 until spring. The GRDO (and possibly personnel from the drilling and camp contractors) will conduct inspections every four to six weeks throughout the winter. Run temperature logs in the vertical well as necessary during these periods. Transportation for these inspections would be by helicopter.

- Begin site reactivation in late April or early May 1995. Run final logs in the vertical hole. Perform water-sampling operations. Run geophysical studies such as vertical seismic profiling.

- Commence drilling the deviated hole. For sidetracking, mill out the casing at the appropriate depth and set the whipstock between 800 and 1,300 ft. A 100-ft cement plug will be set at the bottom of the casing and another 50-ft cement plug will be set just below the whipstock. Mill through the casing, build the angle, and establish the slant core hole underneath the dome by continuous coring in the same manner as the vertical hole.

- Complete the slant portion of the deep hole at the main site.

- Run final logs in the slant hole at the dome site.

- Cut and pull the uncemented nested portion of the tubulars. Plug and abandon the hole at the dome site (Section 8.9).

- Begin the demobilization of the rig at the dome site.

- Restore the dome drill site, demobilize the camp, and restore the campsite.

- Perform the final NPS and State of Alaska inspection and final site restoration, remove any remaining survival equipment, and abandon the site in fall 1995.

8.3.1 Initial Season of Operations, Winter Shutdown, and Possible Winter Operations

Operating in this modified single-phase mode will greatly reduce the number of helicopter flights from the amount required by a three-phase operation (with three mobilizations and demobilizations) proposed previously. Moreover, it will reduce the number of operational days in the park. In the first year of the split operations season, the 4,000-ft vertical hole and 660-ft slant hole can be completed with reasonably favorable drilling conditions.

The operation should conclude before the end of the barge season the following year so that material and equipment can be barged soon after removal from the drill sites. If not, the equipment will be demobilized upon cessation of the project, removed from the park, and stored at King Salmon until sea transport once again becomes available.

<u>Advantages and Disadvantages of Winter Operations</u>

Another advantage of the single-phase mode of operation is avoiding drilling and coring during the coldest weather months of the year, November through March, when accidents of all types are more likely. Inclement weather, subfreezing temperatures, and protracted periods of darkness are all conducive to accidents.

Helicopter support would be constrained by the weather and by the short hours of daylight. Often the short daylight window coupled by poor weather would prevent an adequate number of helicopter support flights. Flying to the dome site from King Salmon could be difficult compared to other times of the year (see Chapter 11.0). There are protracted storm periods in the winter, including the possibility of whiteouts, which would be a dangerous flying situation.

Short hours of daylight would also constrain inspections of the waterline and support of the ash-flow site. For example, crew change at the ash-flow site would become tenuous.

In a winter operation 20 to 30 percent more fuel would be necessary to heat water tanks or bladders. A far more elaborate survival system would be necessary at the ash-flow site. Water and fuel lines could rupture at the drill sites. Response to any onsite or offsite spill would also become tenuous. Industrial-type accidents would be more probable.

If winter operations were planned, more waterline heating stations may be necessary because of the extreme difficulty of keeping the waterline flowing. A double waterline would be essential. Because of the extreme winter temperatures, it would probably be necessary to build shelters around these stations so the equipment could function. Maintainance of a waterline buried in snow could become more difficult. However, the snow would act as insulation for the waterline, but foot travel to maintain the lines over the same snow would become difficult. It would probably be very difficult to maintain an adequate water supply for well control, which could pose severe safety problems. Any water supply for the ash-flow site is problematical because the river does not flow in winter.

It could become very difficult to extract water from Lake Mageik through thick ice during the winter. The lake could be frozen solid; it is unknown. It might be necessary in this case to drill for a water source close to the dome site and the ash-flow site as well. Water wells were considered earlier in the project.

On the other hand, tourism in the park would be virtually nonexistent. There would be no problem obtaining support in the King Salmon area that time of year because of the total lack of competing activities.

In light of the above-mentioned factors, it is estimated that 35 to 50 percent more time would be spent in the park to accomplish the same tasks that could be accomplished in the summer months. The risk of total or partial failure (which would be intrusion into the park with no scientific results), while difficult to quantify, would be greater. Premature abandonment would involve carrying out unanticipated quantities of tubulars, cement, fuel, and drilling fluid additives that were mobilized, entailing additional demobilization flights. Because the site is not on permafrost, it is uncertain if winter operations would mitigate the environmental problems associated with the operation. The disadvantages of operating in the winter months far outweigh the advantages of operating in these months.

8.3.2 Number of Rigs in the Park

Establishing the two deep core holes at the dome sequentially rather than simultaneously will provide advance knowledge of the drilling conditions for the second deep core hole at Novarupta Dome. The hole design at Novarupta Dome specifies a single pad (Figure 7-1), one (not two) casing strings, and requires fewer rig days in the park and reduced helicopter support. A smaller rig is adequate to establish the hole at the ash-flow site.

The project will utilize a diamond core rig that is adequate for the difficult drilling conditions which could be encountered at Novarupta Dome. The winter shutdown also allows time to retrofit the rig, if necessary.

8.3.3 Mode of Main Mobilization and Support

Carrying out the main mobilization and demobilization by helicopter (see Chapter 11.0) from King Salmon is a simple, safe, and conservative approach. Support facilities are in King Salmon and materials can be stored there. Mobilization from the Shelikof Strait was considered, but rejected on the basis of more complicated logistics, storage of fuel near wetlands or tidal areas, severe weather, and associated marginal cost savings.

8.3.4 Helicopter Support

Supporting the ongoing operation from King Salmon by means of a support helicopter is a simple approach to transporting supplies and personnel to the remote field camp (see Chapter 11.0). Helicopter support will allow convenient air freight shipments from Anchorage and more distant areas, convenient resupply from the King Salmon area, and convenient mobilization for crew changes and itinerant personnel traveling to and from the drill site. The support helicopter should be able to support the dome and ash-flow site operations for the three to four weeks that it will take to establish the hole at the ash-flow site. Also, operating out of King Salmon is convenient to further logging of the core from the drill sites. Arrangements will be made for storage and other support facilities at King Salmon.

8.4 Drilling Fluids, Lost Circulation, and Fluid Management

8.4.1 Discussion of Drilling Fluid System and Lost Circulation

Drilling muds are fluids that are used to cool the bit, to lubricate the drill string, and to flush drilling chips from the face of the bit to the surface, thereby keeping the hole clean. In some operations, potable water has been used as a drilling mud. Unfortunately, pure water is a poor lubricant. It has low viscosity and therefore does not lift chips readily. Also, pure water can cause difficulties if the formation is slouchy or if it contains expanding clays. Thus drilling fluids are treated with additives that increase its lubricity and viscosity. Often this is accomplished through the use of natural materials such as bentonite clay. However, clays alone can flocculate if the water chemistry is not correct. Thus materials such as sodium carbonate are added to increase the pH. In addition, polymers will also be added if the rods begin to chatter in the hole. The design of the mud system often changes as a hole progresses and temperatures increase.

Under normal drilling conditions, muds are pumped down the inside of the drill string. They return to the surface in the annular region between the string and the hole wall. Sometimes this circulation is lost when the hole encounters a permeable or fractured formation. Such lost circulation events are common in volcanic formations. They can cause numerous drilling difficulties. Without circulation, it is difficult to cement a casing to the formation because the cement may follow the drilling fluids into the lost circulation zone. Lost circulation can also cause a mixing of fluids in subsurface aquifers. This makes fluid sampling for scientific purposes difficult because the samples are no longer representative of in situ conditions. Finally, lost circulation can lead to blowout conditions when the hydrostatic head of the fluid in the hole is decreased, allowing high

temperature formation fluids to boil. For this reason, efforts are always made to maintain circulation when high downhole temperatures are prevalent. Materials and cements are employed to plug lost circulation zones and maintain circulation.

Lost circulation would normally be characterized by a drop in the flow rate of outlet fluid. There would also be a decrease in the inlet pressure reading. Fluid losses could range from 200 to greater than 50,000 gal per day. Therefore, rapid response of the drilling crew is necessary.

Remedial action in lost circulation conditions often consists of pumping plugging materials into the permeable portions of a formation (Table 8-3). A constraint on such materials is that they pass through the orifices in the bit and in the annular region between the drill string and the hole wall. Diamond core drilling poses a special problem in that this annular gap is small--approximately 1/4 in. This small annular gap facilitates well control, however (Sections 8.4.2 and 10.2).

If the use of plugging materials fail, special cements and special additives to immediately precede the cement will be employed. These nontoxic cements set quickly; therefore, they are not a major disruption to the drilling schedule. These cements are thin and may be pumped down the drill string. Usually cement treatments are attempted soon after a lost circulation zone is encountered. If the lost circulation zone is thick, several cementing operations may be attempted in quick succession, each aimed at new loss zones encountered as the hole is advanced. Cementing operations will require the presence of special mixing and pumping equipment and trained crews (Section 8.7). Cementing operations also generate solid wastes that will be removed from the park (Section 8.6.3).

It is not realistic or possible to outline a procedure for all lost circulation problems in this plan. Furthermore, the phenomenon of lost circulation, does not, in itself, automatically imply a well control problem.

Sandia National Laboratories is currently developing special equipment for lost circulation problems in geothermal environments (Loepke et al., 1990). Encouraging field trials with specially selected lost circulation materials was accomplished on a recent DOE/OBES-sponsored hole that was engineered by the GRDO.

8.4.2 Fluid Management and Treatment of Lost Circulation

Drilling fluid additives used in this operation will consist primarily of degradable polymers or clay-type minerals and are listed in Table 8-3. Small amounts of rod grease will be used. Various lost circulation materials will be utilized as needed. Only nontoxic drilling fluid additives will be used. Additives in concentrated form may be considered toxic. Additives as used in the formation will be nontoxic. Barite will be on hand if it is necessary to weigh up the drilling fluid. The drill cuttings could be useful either as a weighting material or, more practically, as a component of material to be added during lost circulation. Lost circulation materials may consist of mica or other small gravel, and other environmentally safe materials. Material safety data sheets for all drilling fluid additives will be presented as part

Table 8-3

List of Drilling Fluid Additives and Lost Circulation Materials

Operation	Drilling Fluid Additives To Be Used
Drilling through surface casing low drilling temperatures, <80°C	Western sodium bentonite,* calcium carbonate, sodium, calcium, and potassium hydroxide would be used.
Drilling to intermediate casing string depth, intermediate drilling temperatures 80°C $\leq$ T $\leq$ 150°C	Liquid anionic polymer for viscosifier and stabilizer* of finer grained sediments would be used.
Drilling beyond intermediate casing string, high drilling temperatures >150°C	Wetting agents and detergent for clear water and low solids drilling fluids,* artificial clays,** sodium carboxy-methyl-cellulose-filtration control agent,* polyanionic celluloses,* maleic anhydride copolymer filtration control agent and viscosifier, polymeric high temperature filtration control agent, acrylamide copolymer,* liquid polymeric high temperature thinner,* lignosulfate thinners, chromium free,* and high temperature lubricants, and thermavis would be used.

Lost Circulation Materials

Various fibers, flakes, and granules, shredded paper,**
Mica (fine, medium, coarse),
Walnut shells (fine grind),
Sawdust,
Rubber tires (fine to medium grind), and
Cotton seed hulls.

Weighing Materials

Barite

*Tested under shrimp bioassay using EPA protocol Federal Register, Vol. 50, August 26, 1985, pp. 3431-3433.
**EPA protocol tests pending.

of the permitting process. If existing information is available in bioassays such as for shrimp, it will be provided. Drilling fluid additives will be stored in water-proof containers, out of the elements.

Drilling fluids will be mixed in an approximately 300-gal mixing tank. The fresh drilling fluids will be stored in a portable tank with an appropriate 1,200-gal capacity.

The State of Alaska requirements are to maintain circulation and to maintain annulus fluid levels within 100 ft (30 m) of the surface. This requirement will be followed at the dome site until casing is set at approximately 1,300 ft (540 m) and cemented with returns to the surface (Figure 7-1). In the event of extreme lost circulation problems during this phase, the presence of a cementing crew onsite may be necessary. However, once the intermediate casing string is successfully cemented, a waiver will be requested for the requirement to maintain the 100-ft level of drilling fluid in the annulus. The waiver will be requested for those conditions when temperature and fluid loss (actual annular fluid level) indicate it is safe to proceed. This request will be made for the following reasons:

- No substantial fluid production is planned. (Some small volumes of fluids may be produced, but only for scientific sampling.) Because of depth and temperature considerations, this core hole must be permitted as a geothermal well. In reality, however, it is a scientific hole to obtain core and temperature measurements. It is in no sense a well to produce geothermal energy.

- Well control during coring is facilitated by the narrow annular dimension of approximately 1/4 in. (~0.6 cm). The narrow annular dimension would at the same time limit and cool any influx from the formation.

- Drilling fluid can be pumped down the annulus, as well as the interior of the rods.

- Cementing requirements for tubulars beyond the intermediate casing string are not as critical (Section 8.7) because well control is maintained by the intermediate casing string. The blowout preventer with the choke and kill lines provides well control and prevents blowouts.

8.5 Returned Drilling Fluids

8.5.1 Fluid Management Plan

A schematic diagram of drilling fluids handling from mixing to disposal is given in Figure 8-4. The following sequence will be employed:

- Fresh water will be sent from a storage tank to an approximately 300-gal mixing tank.

- Drilling fluid additives and lost circulation materials, if necessary, will be mixed in the water in a mixing tank.

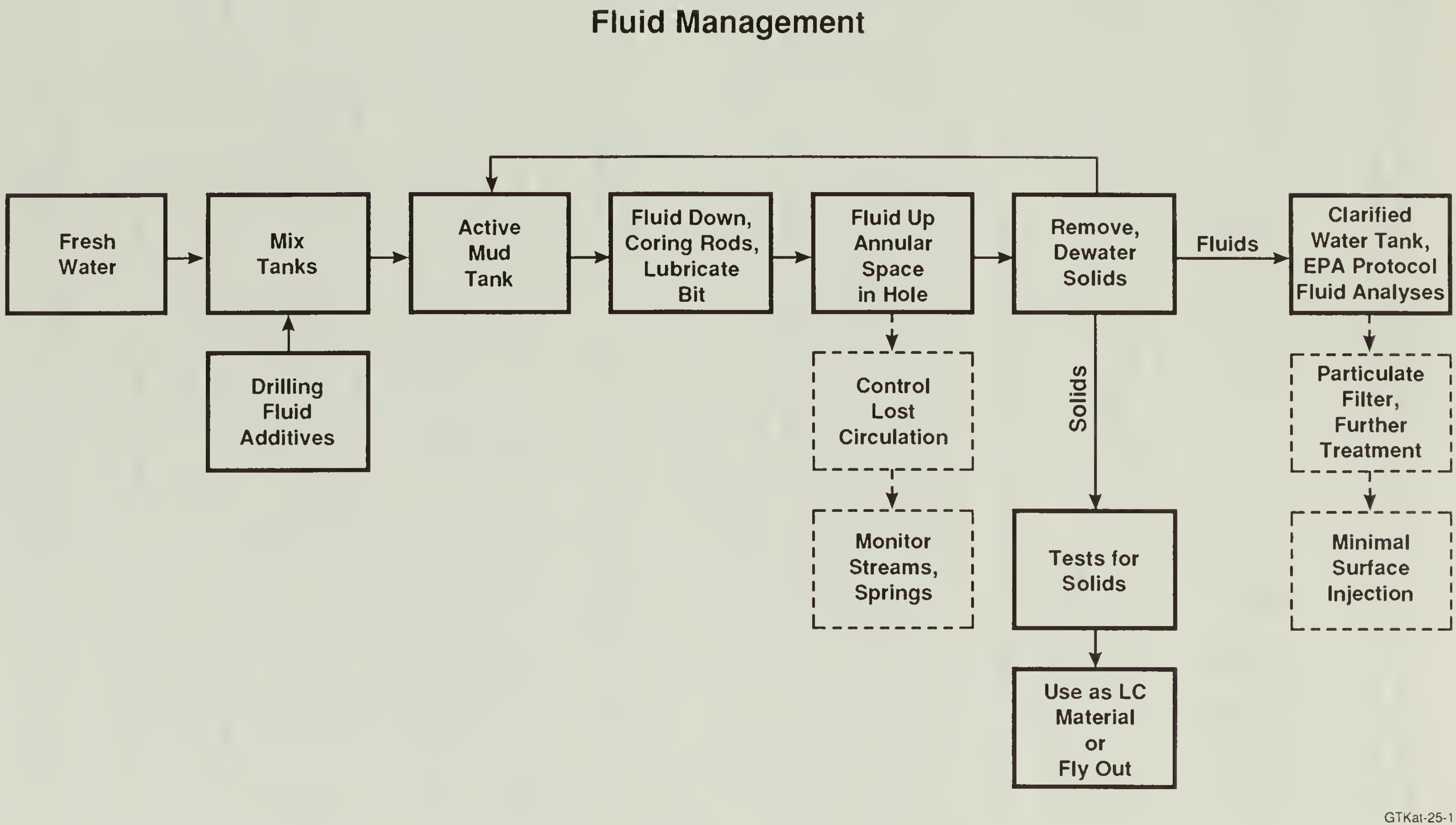


Figure 8-4. Fluid Management Flow Sheet

- Drilling fluid will be pumped down coring rods from an approximately 1,200-gal mud tank. The drilling fluid will lubricate the coring (or reaming) bit and carry cuttings to the surface.

- Fluids reaching the surface will pass through a tank, shaleshaker, desilter (mud cleaner), and centrifuge. Solids will be dewatered by the shale, desilter, and the on-line centrifuge (Section 8.6.1), or fluids will be returned directly to the mixing tank.

- When fluids can no longer be used, the solids will be removed mechanically as indicated above. The fluid will be run through a filter system including a particulate filter and sent to the settling (leaching) pond. Such fluids will be sampled and analyzed according to EPA protocol.

8.5.1.1 Amounts of Water To Be Used at the Drill Sites

Normal water usage at the dome site will be approximately 10,000 gal per day during the reaming out of the hole to set the conductor pipe and to set the surface casing string. During coring stages, the volume of water used will be approximately 3,000 gal per day. Without manifestations of lost circulation, fresh water use could be reduced approximately twofold or more. In addition, recycling and dewatering the solids could decrease fresh water use further, though the hole at the dome site might continue to absorb 500 to 600 gal per day. During periods of complete lost circulation, water use could increase to approximately 50,000 gal per day. An average of approximately 5,000 gal per day of water will be used to make drilling fluids at the dome site.

Drilling fluids returning to the surface will be recycled many times. If the drilling fluid can no longer be recycled, it will be sent through additional treatment stages. The fluid will be treated as necessary, e.g., by adjusting the pH to remove metals. Once this unpotable water is free of drilling solids, grease, and most polymer and it is PH-adjusted (if necessary), it will be allowed to percolate into the ground, along with grey water from the camp (Section 12.3). Fresh and returned drilling fluids will be sampled for analysis according to EPA protocols. Fresh drilling fluids will be sampled whenever drilling fluid additives are changed. Returned fluids will be monitored whenever a new formation is entered. In the unlikely event that water has high concentrations of toxic elements brought up from the formation that cannot be removed by chemical treatment, it will be helicoptered to the Bristol Bay area for shipment to an approved disposal site (if it cannot be reinjected back to the same horizons from where it came).

Much of water used will be lost to the formation and the rest must have solids removed and must be recycled. At some time it will no longer be practical to continue recycling this drilling fluid. It must then be treated and sent to the settling pond. No more than an average of 1,000 gal per day will be sent to the settling pond (leach pit).

At the ash-flow site, water use will be less. During periods of lost circulation, approximately 15,000 gal per day will be used. During reaming,

approximately 8,000 gal per day will be used. Overall, an estimated average of 3,000 gal per day will be used at the ash-flow site.

8.5.1.2 Maintenance of Complete Circulation at the Ash-Flow Site

The drilling fluid additive program at the ash-flow site is of great concern because of the proximity of the hole to the River Lethe. There are four reasonable options for establishing this hole that address this concern:

- Drill with water only,
- Maintenance of complete circulation,
- Limit the drilling fluid additives to water and clays, and
- Air drill the hole, muting the compressor noise.

The first option appears to be most conservative. The hole will be drilled under the river, never closer to the river than 200 ft. The second option would be satisfactory if it can be accomplished. The third option should not cause any drilling fluid additives to enter the River Lethe if the fractures are not connected to the river (this will be readily discernable during drilling). The fourth option should be satisfactory from a well control perspective for the hole depths planned. A decision will be made based on the drilling conditions encountered.

8.5.2 Monitoring Streams and Springs in the Valley

The proposed settling pond for the dome drill site is inside the tephra ring and far from nearby streams (Figures 4-1, 4-4, and 5-3). This pond will be in reworked pumice that is away from all vegetation. The water in this pond should percolate immediately.

Several itinerant streams form inside the tephra ring during the snow melt season, with estimated summer month flow rates of 20 to 40 gal per min. This is comparable to the projected water use inside the tephra ring for both the drill site and the camp. This water seeps and immediately disappears into the pumice. No fresh water springs are seen from this snow melt.

Monitoring will be conducted in selected streams and rivers of the Valley of Ten Thousand Smokes to check for signs of drilling fluid from either the surface fluid or the lost circulation (Table 8-4). Monitoring will include measuring levels of salts commonly used in drilling fluids. Monitoring will also include checking for polymer from drilling fluid and polymer decomposition products. Places to be monitored will include the following (Figure 5-3):

- areas on the upper, middle, and lower River Lethe;
  - upper river--above the ford above the ash-flow site;
  - middle river--at the ford to the River Lethe;
  - lower river--at Three Forks;
- areas on upper Knife Creek (including one or more places where water seeps out of the ash-flow tuff above Knife Creek) and a location on the lower Knife Creek at Three Forks below where fresh water springs enter; and
- the midvalley thermal springs.

Table 8-4

List of Sample Analyses

<u>From Drilling Operations</u>
Fresh drilling fluid
Returned drilling fluid
Cuttings and drilling sludge
<u>From Streams, Rivers, and Springs</u>
Waters of the Knife Creek and the River Lethe
Various springs and seeps in the Valley of Ten Thousand Smokes

Streams and rivers will be monitored every two weeks for the first month of drilling and monthly thereafter during the first drilling season. If no trace of drilling is found during the first year, the streams and rivers will be monitored every eight weeks during the second warm season. Analysis will be conducted in Anchorage or Fairbanks, with more cursory analysis to be conducted onsite. Appropriate EPA-approved protocols will be followed under the Clean Water Act.

If there are severe lost circulation problems at shallow depths, nearby terrain will be examined to make certain that surface emergence of drilling fluids (a spring) has not occurred. If such a spring is created, drilling techniques will be altered. The deeper the operation penetrates, the less likely it is that this will occur.

Measurements will be performed before drilling commences upon activation of the camp to establish a baseline in the streams and springs. In addition, careful water measurements have been performed at over 30 stations in the valley (Section 5.3) (Keith et al., in preparation). If drilling fluids are found in the fresh water system of the park by monitoring or by other means, the drilling will be stopped. The problem will be corrected before drilling continues.

8.6 Drilling and Other Solids From the Operation

8.6.1 Drilling Solids (Cuttings)

The volume of returned drilling solids before dewatering is estimated to be approximately 30 to 80 yd^3. Drilling solids will either be reinjected into the hole along with other lost circulation materials or they will be flown out of the park. Solids will be tested to determine their health and safety characteristics. Because the TCLP tests of volcanic types from the area showed almost no sign of RCRA leachates, it is unlikely that these solids will pose a problem (see Section 5.3 and Appendix C).

The returned drilling solids will be either put into a site approved for solid drilling waste or fixed with cement and placed in a permitted municipal landfill.

Solids will be analyzed each time that new stratigraphy is cored. The chemical analyses in Tables 5-1 and 5-2 provide a guide for certain element concentrations.

8.6.2 Nondrilling Solid Waste

Combustible nondrilling solids will be incinerated (Appendix A), if possible. Noncombustible nondrilling solids will be compacted whenever possible. These solids will be flown out of the park for suitable disposal. Total volume of nondrilling solid waste to be flown out should be less than 30 yd^3 when compacted. The manager of the Bristol Bay Borough indicated informally that nondrilling wastes could be disposed in the borough landfill.

8.6.3 Solids From the Cementing Operation

Most cementing operation designs include an amount of excess cement for safety. Excess cement will be removed from the park and stored at an ordinary landfill or with drilling wastes.

8.7 Cementing

Cementing in fractured volcanic formations can be difficult. Every effort will be made to control lost circulation in the coring and in the reaming operations down to conductor pipe and casing depths. This will help ensure a successful cement job, i.e., the lifting of the cement to the surface in the annular space between the pipe and the formation.

The bottom of the conductor pipe will be cemented in the upper formation. The surface casing pipe and the intermediate casing string will be

cemented throughout their length. High-temperature cement will be pumped in the conventional manner--through the interior of the pipe and lifted to the surface through the annular space between the pipe and the formation. If cement is not lifted to the surface, the top of the cement will be measured with temperature logs. Depending on the distance of the cement from the surface, it may be possible to pour cement from the top to complete the cement job. If this fails or is impractical, it may be necessary to perforate the pipe and inject the cement under pressure around the pipe, which is called a squeeze job.

Cementing of the conductor pipe and casing string will be accomplished by a company experienced in geothermal cementing. Cementing crews will be flown in and out as needed. It is expected that the need for the cement crew will diminish after the intermediate casing string is set. When not onsite, the 2- to 3- person cementing crew will be on call.

A waiver of the State of Alaska regulations is requested regarding cementing. The State of Alaska regulations require the cementing of all strings of tubulars. Most geothermal regulations were not made for scientific core holes (slim holes), but for geothermal production wells, which are not slim holes. Engineering considerations for these two types of wells are different in many respects. As mentioned, one principal factor in diamond-cored wells is the very narrow annular dimensions between the coring rod and the hole---1/4 in. This narrow annular dimension makes deployment of materials like cement and lost circulation material more difficult. The rods interior to the casing are usually pulled after coring and before any well testing program. Well control will be maintained by the intermediate casing string. The additional cementing of these interior rods is often impractical and perhaps impossible.

8.8 Hole Measurements Plan

Measurements in core holes will include temperature logging and pressure monitoring; core hole deviation surveys; borehole televiewer measurements with a slim, high-temperature tool; spectral gamma-ray measurements; downhole fluid samplings; and possibly, special logs provided by the PIs. The vertical hole will be logged before the deviated hole is kicked off because simultaneous access to both vertical and deviated holes for measurements is difficult. Temperature logs will be run frequently during the drilling and coring operations. The measurements will also be run during and after winter shutdown and inspection periods, and before site abandonment.

PIs and associated scientists will provide a continuous lithology log of the holes from the core. Many specialized measurements will be conducted later on portions of the core. All data will be made available to permitting and scientific groups.

8.9 Plugging and Abandonment

For well abandonment the uncemented interior tubulars will be cut and removed in the final abandonment procedure. As many of the nested coring rods as possible will be removed from the holes. Aquifers that are identified will be cemented and sealed off. A 100-ft cement plug, at a minimum, will be set

at the bottom of the casing after temperature equilibrium has been reestablished. The holes will be filled with completion fluid, and a cement plug that is no less than 25 ft thick will be set near the surface. Conditions will determine exact plug lengths, but the lengths will meet or surpass all permitting requirements. Pipe protruding from the holes after the setting of the cement plugs will be cut and capped off below ground level.

8.10 Summary of Critical Operational Problems and Operational Contingencies

It is important to reiterate that drilling and operation conditions in the Valley of Ten Thousand Smokes are largely unknown. Even with a specific plan of operations, field decisions will be necessary, requiring consultation with and approval from the NPS. Critical operational problems associated with drilling include the following:

- Water Supply and Waterlines Water is necessary to support drilling. A reserve of a minimum of 80,000 gal of water is necessary to stem lost circulation and maintain well control (see Section 10.2.). Lake Mageik is glacier-fed and is a reliable water source. (It may be necessary to cut through the ice at the beginning of the project.)

  Maintaining the waterline will be a critical task. Having pumping and heating stations will result in lower and safer line pressures and prevent freezing. There could be some fresh water spillage of a few 100 gal per day from the surge tank at each pumping station or within the tephra ring. (Inside the ring itself, a much larger volume of water from snow melt percolates in season.) It is felt that laying and maintenance of the waterline will pose little danger of permanent environmental damage. Bears are known to damage waterlines. Patch kits and extra pipe will be available as a contingency. (If useable water is found during the early drilling stages, the water well option will be reconsidered.)

- The Effects of Loose Pumice on Drilling At the main drill site, the depth where the pumice becomes consolidated is not certain but is estimated at 100 ft (~33 m) or less. This is based on examination of the rock in gullies near the dome. Project scientists state that large boulders from Novarupta Dome to 6 ft in diameter may be buried in the unconsolidated pumice.

  The conductor pipe (Chapter 7.0, Figure 7-1) will be driven through the loose pumice by a casing hammer or other suitable techniques until a consolidated formation is reached. The casing may also be rotated down through the pumice by the rig. Equipment using the sonic technique may be used, if available. The conductor and casing pipe lengths will be increased according to the amount of unconsolidated pumice. The conductor pipe will be cemented as well as possible to the consolidated rock. Care must be taken not to erode the cement drill pad with drilling fluid circulation while working in unconsolidated pumice. The degree of consolidation could impact efforts to maintain circulation while the conductor pipe hole is reamed. Supplementary cementing of the conductor pipe from the top may be necessary.

In a dry period the loose pumice may become a hazard for helicopter operations. Water can be used to keep pumice and dust down as required. A mat of some type will be available to fix the pumice at the landing pad, if necessary.

- <u>High Core Hole Temperatures and Pressures</u> (See Section 10.2.)

- <u>Weather for Helicopter Flying</u> Supplies for the operation are critical. Sufficient materials for 10 days will be kept on hand. Weather conditions in this part of Alaska could interrupt helicopter support to the main site for a significant amount of time (Section 11.4).

- <u>Operational Contingencies</u>

  - During drilling and reaming, there is a possibility of twist off. It may be necessary to skid the rig over 5 or 10 ft to start a new core hole. The old well would be plugged and abandoned. If the well has been advanced far enough, a fishing job may be warranted. Such decisions will be made in the field.

  - <u>Deviated Hole and Whipstock</u> If drilling conditions are not satisfactory for the setting of a whipstock, it will be proposed that a second hole will be drilled from the surface and from the same pad if at all possible.

  - <u>High Temperatures or Poor Drilling Conditions</u> If high temperatures or extremely poor or unfamiliar drilling conditions are encountered, drilling plans may be altered. The well will not be advanced if dangerous conditions persist.

- <u>Smaller Rig for Shallow Slant Core Hole</u> It is advisable to bring in a smaller rig to drill the shallow slant core hole at the remote site. The work on this core hole is planned to be in parallel with the vertical hole at the dome site. The support helicopter should be able to support both rigs simultaneously, necessitating fewer helicopter flights in the park. However, if delays arise, work will commence on this ash-flow core hole while problems at the main site are rectified.

- <u>Disposal of Liquids and Solids from Drilling</u> The dewatering of solids and the attendant recycling of drilling fluids will greatly mitigate the disposal problem of returned drilling fluids by reducing the volume of water used. It is not routinely attempted on-line in remote areas. This processing will also reduce the amount of drilling solid volume and render the solid material in better form for fixation. Cuttings will be reinjected during periods of lost circulation or flown out of the park and fixed at a suitable landfill or placed in an area permitted for drilling solids.

  The drilling fluid consists largely of clay and polymer. The polymer will be used (and largely degraded) at higher drilling temperatures. At lower temperatures the polymer will force a filtercake on the rock. All the material is nontoxic. Furthermore, the total daily production

of common drilling salts by drilling activities is small compared to the drilling salts generated by the natural leaching processes in the valley and the effluent from the volcanic thermal springs (Appendix C). These salts from natural phenomena, in turn, are carried by Knife Creek and the River Lethe systems (Table 4-1).

- Hydrologic Effects The hydrologic system of the Valley of Ten Thousand Smokes and the hydrothermal system associated with the volcanoes have been under continuous study for a decade. Additional data were provided during the field season in 1991 (Appendix C) and more data will be provided in 1992. Monitoring of nearby streams and designated springs during and after operations will help ensure that drilling effects are not manifested in waters nearby the site.

- Lost Circulation Because of narrow annular volumes between the wall of the hole and coring rods, there are limitations on the materials that can be employed to retard fluid loss. Success in retarding fluid loss with special lost circulation materials was attained in recent diamond coring operations, but cementing equipment will be maintained onsite to be used when necessary.

8.11 Special Engineering of Drilling Operations

The GRDO is providing special engineering of certain critical items listed below for the Katmai Drilling Project. The corresponding items available from industry, while satisfactory for the project, could be further improved for diamond core operations. Individual components to assemble these items are available. Existing commercial equipment designs may be scaled down for a smaller operation such as this. No aspect of the operation depends on a new invention. Candidate items to be engineered for the Katmai Drilling Project include the following:

- Additional high-temperature drilling fluid additives that are environmentally safe. The available polymers break down at extremely high temperatures; therefore, penetration (coring rates) drops. A degree of success in developing appropriate additives will increase penetration rates, resulting in less time in the park to conduct the operation. Certain high-temperature polymers are being tested by firms in the industry.

- Continued research in optimizing lost circulation additives for diamond core drilling. The successful research in high-temperature lost circulation problems will emphasize the diamond coring mode of operation. Continued success in this work will minimize fluid loss to the formation, and, in general, the potential for well control problems will be decreased. This work is ongoing at Sandia National Laboratories.

- Downsizing cement pumping and staging equipment. Much of the existing cement units have been designed for oil field applications and are bulky for this type of diamond core operations. Some service companies have half-skid cement units that can meet the requirements for this project, but further scaling of this type of equipment is

necessary to optimize it for operations. Such downsizing should be relatively simple.

- Instrumentation for downhole temperature measurements during coring will be developed. This will be based on a downhole microprocessor/memory system attached to the core tube. In this manner downhole temperature data will be obtained each time that the core is pulled. (Temperature tabs reading maximum temperatures and high temperature thermometers are already available and work successfully.)

- Separation of drilling solids from waste fluids. The technology for dewatering of drilling solids exists from the oil field industry. This process may be scaled down somewhat further for this operation.

9.0 SAFETY

9.1 General Policy

The GRDO will be responsible for the overall safety of the operation. Levels of responsibility will be established between the GRDO and all parties in the field.

All applicable State of Alaska Occupational Health and Safety Administration (OSHA) regulations will be followed. Compliance with state OSHA regulations automatically ensure compliance with federal regulations. Discussions have been in progress with the State of Alaska Department of Labor, Division of Labor Standards and Safety.

Appropriate standards of the American Petroleum Institute will be followed, especially with respect to blowout prevention and welding. Helicopter safety regulations and procedures will also be followed (Chapter 11.0).

A site-specific SOP will be written for the Katmai project covering potential hazards, responsibilities, and personnel assignments among the groups in the field; personnel safety equipment; emergency preparedness; and professional conduct. A formal safety analysis will also be written. This analysis will probably be related to the site specific SOP, but will probably be a separate document. Generic safety plans for geotechnical field sites have been provided by the GRDO that include hydrogen sulfide safety and situations where numerous agencies are working together in the field. These safety plans and the safety philosophy for remote geotechnical sites are included in Appendix B (Wemple, 1989). Those formal, internal documents in Appendix B realistically outline the safety considerations that will be extended in the site SOP. They show the degree of concern to be given to safety.

9.2 Medical Services and First Aid

Arrangements will be made to transport injured or ill personnel by the camp helicopter to the clinic in Naknek, Alaska, which is the nearest appropriate medical facility. If necessary, the patient can be flown to Anchorage for further medical treatment after being treated and stabilized at the clinic. Due to the remote location of the project, an emergency medical technician (possibly a part of the crew) will be present onsite. Table 9-1 provides a list of associated planning activities for medical emergencies that must be addressed in project SOPs. First-aid training will be given to all field personnel.

9.3 Survival Tent

All crew members will become familiar with the survival tent facilities for possible situations when weather prevents access between the ash-flow drill site and the main camp.

Table 9-1

Planning Activities Necessary for Medical Emergencies and Illness

Qualifications and Credentials Appropriate for Medical Provider at Katmai Drill Site:

Advanced cardiac life support and advanced trauma life support credentials;

Alaska licensure;

Midlevel medical provider or paramedic rating with protocols in place to render appropriate remote site care for injury or illness; and

Certification with self-contained breathing apparatus experience in wilderness emergency medicine.

Planning Activities To Prepare for Medical Emergencies:

Decisions on equipment; communications, stabilization, cardiac monitoring, and bandaging supplies; irrigations supplies; or other supplies;

Stabilization and treatment area;

Relationship to be established with emergency medical technicians in the Bristol Bay area and Anchorage emergency physicians or family practice physicians;

Helicopter transport to be investigated under various patient conditions;

Decisions on medications to keep onsite; and

Appropriate licenses and certifications.

9.4 Communications

Because of the remote location of the site, elaborate communications will be established. The following communication links will be instituted:

- commercial or portable satellite radio-telephone communications linking the dome drill site to the Anchorage area and beyond;
- commercial or portable satellite telephone service from the site support area in King Salmon through the Bristol Bay Telephone Cooperative;
- a radio net between the main drill site, the remote drill site (during the few weeks that it is active), the camp, and the site support facility at King Salmon;

- ground radios available at each operations site to talk to support helicopters while they are in flight;
- ground radios (walkie-talkies) for personnel maintaining the waterline to communicate with the drill site and camp.
- a radio net between the main drill site and the USGS in Anchorage;
- access to the NPS radio net requested for the conduct of certain business and emergencies; and
- an emergency communication procedure set up between the drill sites and the clinic at Naknek.

10.0 HAZARDS, HAZARD MITIGATION, ACCIDENT CONTAINMENT, ACCIDENT PREVENTION, AND STORAGE PLANS FOR CRITICAL ITEMS

10.1 Policy for Emergency Preparedness

The policy of the fielding agencies is to develop and maintain a state of emergency preparedness for the following:

- the health and safety of personnel,
- the protection of the environment,
- the protection of equipment and property,
- the necessary scaled-down operations under emergency conditions, and
- the resumption of normal operations as rapidly and economically as possible.

Required training includes the following:

- oil spill response training for all drill crew,
- hazard materials handling for at least one member of each shift on the rig,
- hydrogen sulfide training for all permanent camp occupants,
- CPR/first aid for all permanent camp occupants, and
- blowout prevention training for all drillers.

10.2 Anticipated Core Hole Conditions, Temperatures, and Pressure

The drilling conditions at Novarupta Dome are poorly known because drilling into a similar large vent has never been attempted and the system is so young that only the uppermost portion is exposed. Temperatures greater than 650°F (300°C) may be encountered. These temperatures are near the limit of drilling technology. There are hot spots on the surface of the Turtle (Figures 4-1 and 4-4), but none on the floor within the tephra ring. A loading chamber, similar to a lubricator, will be used for the wire line coring when temperatures exceed 175°F (80°C). Downhole temperatures will be measured with temperature tabs or thermometers during every coring run. If appropriate, the depth of the annular fluid level will be estimated at the end of each coring run and during reaming operations. An echo meter or other appropriate method will be employed.

Pressures in the vent are not known. Due to the fractured nature of volcanic vents, underpressurized fracture formations are anticipated. Pressure transients can be controlled with the blowout prevention system (Chapter 7.0), the mud pump (which could add approximately 1,000 psi to a column of fluid), choke lines, kill lines to pump fluid down the coring rods and annulus simultaneously, or weighing of the drilling fluid rates. Automatic monitoring

will be performed for inlet and outlet drilling fluid flow rates, pressure, and temperature (Table 10-1). All well control and choke functions will be controlled at two locations: one on the rig floor and one at a convenient location off the rig floor. Both lost circulation and weighing materials will be onsite, if needed. The core hole will not be advanced if dangerous conditions are prevalent.

In the event that well control problems occur, the following action will be taken:

- <u>Underpressurized (fractured) Formations</u> Venting could possibly occur if the column of water in the wellbore is diminished to a large degree by a fractured formation. The venting would occur if the wellbore pressure from the column of water falls below the steam pressure corresponding to the formation temperature at a particular level in the wellbore. A first response would be to pump cold water down the wellbore to temporarily cool the formation below the stream point. Water can be pumped down the rods from the mud pump and/or down the annulus through the kill line. The kill line can be used even if the rods are not in the hole. If control is temporarily regained, lost circulation materials, weighing materials, and lastly, cement can be employed. Onsite fresh water storage will be between 80,000 and 120,000 gal for well control.

- If the core hole is overpressured, the influx will be circulated out through the choke line and weighing materials will be employed. This is the standard drilling procedure in this situation.

At the sign of transient pressure (indicated by a rapid rise of the flow rate of returned fluid), the core hole will be shut-in with the blowout preventer system for observation or equilibration of the core hole pressure. If the pressure tends to fall off after shut-in (suggesting downhole steam condensation and lost circulation), then the core hole is probably underpressurized and cold water will be injected as recommended above. If the pressure remains constant or increases (suggesting an overpressurized formation), then the unwanted effluent will be circulated out the choke line and the drilling fluid will be weighed up to control the pressure using standard drilling procedure.

The narrow annular dimension between the coring rods and the core hole makes the dynamics of core hole control (and drilling in general) different from geothermal wells. While limiting the size of lost circulation material that can be deployed, this narrow annulus tends to simultaneously throttle and cool an influx of steam or water. (A provision will be made to store such influx.)

It is not realistic or possible to outline a procedure for all well control problems in this plan. Rather, the intent is to discuss the importance of well control and training and experience in well control procedures. Control procedures are outlined that have been performed in this type of operation and the dynamics of slim hole drilling in thermal regimes are compared to geothermal well drilling.

Table 10-1

Electronic Monitoring Requirements Identified to Date

Drilling Parameters

Inlet fluid: flow rate, temperature, pressure
Outlet fluid: flow rate and temperature
Net fluid: volume (inlet minus outlet flow rates)

Fuels and Sensitive Liquids

Tank levels
Fluid in mixing tanks

Hydrogen Sulfide

Rig substructure
Rig floor
Mud tanks
Offices
Camp (office, bath, mess, recreation, each row of tents)

Waterline

Pressure
Flow rates
Inlet and Outlet temperature
Volume in surge tank

It may be necessary to cool returned drilling fluid through a cooling tower or heat exchanger. Materials for such a cooling device will be stored in King Salmon (Chapter 13.0). The components of the cooling tower/heat exchanger will be transportable by helicopter. The decision to use the cooling tower will depend upon returned fluid temperatures.

The blowout preventer is available. If well control problems persist, pressurized abandonment techniques must be considered.

The quality and experience of the drilling crew are the most important factors in avoiding or mitigating drilling-induced accidents. The GRDO requires that any firm selected shall provide qualified personnel who are experienced in high-temperature coring operations. The selection of a drilling contractor is a deliberate and painstaking process for the GRDO. Quality and experience of the crew and equipment to be committed are key factors in this selection process. The government-controlled contracting

regulations followed by the GRDO have sufficient flexibility to ensure selection of a qualified company with experienced personnel.

10.3 Plan for Prevention and Containment of Fluid Spills

Liquid drilling fluid additives will be stored safe from outside weather conditions. If necessary, a berm will be placed around this storage area. The fresh drilling fluid will be mixed and kept in a portable mixing tank. Used drilling fluids will be stored in a tank. Fuels will be stored in bladders or barrels and will be kept in a lined area surrounded by berm. The berm will conform to the requirements of 40 CFR 112 (see Appendix D). The inside of the berm may be recessed 1 to 2 ft below the pumice surface. The fluid level of all major fuel tanks and drilling fluid storage will be monitored electrically. All fluid containments will be monitored visually.

Solid drilling fluid additives and lost circulation materials will be kept in storage modules out of the elements. Dewatered drilling solids will be stored in a covered, lined area. These solids will be moved to this area in a portable hopper.

Bermed areas for fuels and other sensitive liquid will be inspected on each shift. Procedures will be posted to be followed in case of a spill, as well as state and federal authorities to be notified. Detailed plans for spill prevention, mitigation, and cleanup are in Appendix D. These plans will also be included in the site-specific SOPs. Bermed areas will be at both drill sites and the camp. Waterline pumping and heating stations will have berms or equivalent containment. Because the pump at the water inlet is very close to the lake, the berm at this site will have a double liner and double layer of geotextile material.

The liners for the berm will have welded joints and will be lined with an organic liner such as polyethelene that will be a minimum of 30 ml thick. Because pumice is prevalent at the dome site, a felt-type geotextile material that will be a minimum of 75 ml thick will be laid between the berm and the impermeable organic liner. There are no direct regulations for secondary containment. However, the thicknesses of the polyethelene and geotextile materials will be consistent with standardized SW-870 of the EPA, titled "Lining of Waste Impoundment and Disposal Facilities" (EPA, 1985).

The spill prevention, mitigation, and cleanup plans require familiarizing project personnel with regulations covering spills of fuel or hazardous materials, and training in both spill prevention and cleanup operations. Absorbent pads will be available for daily use and emergencies on the drill site. Sorbent booms and a skimmer will be available for emergencies involving spills of diesel fuel or other sensitive liquids in water. A contingency contract will be executed with an Alaska firm dealing in spill control. Methods of handling the used drilling fluids are discussed in Sections 8.4 and 8.5.

The approximate total fuel storage for each year, along with many of the fuel-using components, is listed in Tables 10-2 and 10-3.

Table 10-2

Estimated Katmai Fuel Consumption

First Season of 1994

Fuel Use Item	No.	Fuel Total (gal)
Dome Drill Site		
Drill	1	11,000
Drill pump	2	2,500
Generator	2	12,000
Rig heat	2	4,000
Drill site heat	4	2,000
Bladder heaters (propane)	5	7,200
Cement equipment	1	1,200
Utility vehicle	1	1,000
Pipeline pump	5	8,200
Waterline heater (propane)	5	7,200
Compressor	1	1,000
Miscellaneous		1,000
Ash-Flow Site		
Drill	1	1,500
Drill pump	1	250
Generator	1	1,000
Rig heat	1	250
Drill site heat	3	250
Bladder heater (propane)	1	200
Cement equipment	1	250
Pipeline pump	1	250
Waterline heater (propane)	1	200
Compressor	1	100
Miscellaneous		150

Table 10-2 (Concluded)

Estimated Katmai Fuel Consumption

Fuel Use Item	No.	Fuel Total (gal)
Dome Drill Site		
Camp		
Camp trash pump (gas)	1	100
Camp cooking (propane)	1	1,200
Quarters heat (diesel)	12	5,000
Recreation/kitchen/ bath/office	4	2,500
Second Season of 1995		
Dome Drill Site		
Drill	1	6,000
Drill pump	2	1,300
Generator	2	5,000
Rig heat	2	1,500
Drill site heat	4	1,000
Bladder heaters (propane)	5	3,000
Cement equipment	1	3,500
Utility vehicle	1	600
Pipeline pump	5	4,000
Waterline heater (propane)	5	2,700
Compressor	1	250
Miscellaneous		2,000
Camp		
Camp trash pump (gas)	1	50
Camp cooking (propane)	1	500
Quarters heat (diesel)	12	2,500

Table 10-3

Estimated Katmai Fuel Storage

Fuel	Number of Gallons
Approximate Fuel Storage for First Season (1994)	
Diesel fuel	60,000
Jet fuel	4,000
Gasoline	200
Propane	16,000*
Approximate Fuel Storage For Second Season (1995)	
Diesel fuel	30,000
Jet fuel	2,500
Gasoline	100
Propane	7,000

*Not all propane will be be stored onsite

10.4 Hydrogen Sulfide Monitoring

A monitoring system will be assembled to monitor hydrogen sulfide concentrations (Table 10-1). Detectors will be set up in strategic locations in accordance with the hydrogen sulfide safety plan to be included in the SOP. (A general SOP for H_2S monitoring at geotechnical field sites is included in Appendix B). The detectors will monitor locations such as the rig floor, mud pits, cellar, office areas, and camp. On windless days such gasses, if produced, could accumulate within the tempra ring.

The field crew will be trained in the use of emergency portable and fixed breathing apparatus, which will be available in strategic places. The portable breathing apparatus will be used for rescue and evacuation. The fixed breathing apparatus on the rig floor would allow the drilling crew to work for a limited amount of time to either secure the well or carry out procedures designed to abate hydrogen sulfide production.

H_2S concentrations of 20 to 50 ppm produce a strong odor. A concentration of 100 ppm causes loss of smell (see Table 10-4). A concentration of 300 ppm is considered to be immediately dangerous to life and health. The presence of such H_2S concentrations is cause for grave concern; therefore, the H_2S alarm systems would be set well below these values, at 10 and 20 ppm. H_2S abatement procedures could include weighing up the drilling fluid to suppress gas production. H_2S training will be given to all onsite

Table 10-4
Physiological Effects of Human Exposure to Hydrogen Sulfide*

Concentration (ppm)	Physiological Effect
0.02	Odor threshold
0.022	No odor
0.025	Detectable odor
~0.03	Olfactory threshold
0.13	Detectable, minimum perceptible odor
0.15	Offensive odor
0.2	Detectable odor
0.3	Distinct odor
0.77	Faint, weak odor, readily perceptible
3 to 5	Offensive, moderately intense
4.6	Fairly noticeable, moderate intensity
10	Obvious and unpleasant odor
10	Threshold limit value-time weighted average
10	Sore eyes
20	Maximum allowable concentration for daily 8-hr exposure
20	Safe for 7-hr exposure
27	Strong, cogent, forceful, not intolerable odor
20 to 30	Strong and intense odor, but not intolerable
50	Conjunctival irritation is first noticeable
50	Marked irritant action on conjunctiva and respiratory tract
50/100	Mild irritation to the respiratory tract and especially to the eyes after 1 hr of exposure
100	Loss of smell in 3 to 15 min, may sting eyes and throat
100	Olfactory fatigue level
150	Olfactory nerve paralysis
~200	Less intense odor; olfactory paralysis
200	Kills smell quickly; stings eyes and throat
250	Prolonged exposure may cause pulmonary edema
300 to 500	Pulmonary edema, imminent threat to life
500	Systemic symptoms may occur in 0.5 to 1 hr
500	In 0.5 to 1 hr it will cause excitement, headache, dizziness, and staggering, followed by unconsciousness and respiratory failure
500	Dizziness, breathing ceases in a few minutes, needs prompt artificial respiration
500 to 1,000	Acts primarily as a systemic poison causing unconsciousness and death through respiratory paralysis
700	Unconscious quickly, death will result if not rescued promptly
700 to 900	Rapidly produces unconsciousness, cessation of respiration, and death
900 +	Exposure to these concentrations may mean instant death
1,000	Rapid collapse, respiratory paralysis, imminent coma, followed by death within minutes; nervous system paralysis
5,000	Imminent death

*Adapted from "A Critical Review of the Literature on Hydrogen Sulfide Toxicity," by R. D. Beaucham, Jr, J. S. Bus, J. A. Popp et al. (Beaucham et al., 1984). Copyright 1984 CRO Press, Inc., Boca Raton, FL. Used with

personnel. The H_2S safety plan to be written will include a provision to check within the tephra ring for tourists or hikers if the H_2S alarms sound. The tourists would be evacuated to a safe place.

10.5 Waterline

Precautions for normal pressure safety will be exercised in operating a pressurized waterline. Appropriate regulations of the State of Alaska and OSHA will be followed. Pressures, inlet and outlet temperatures, and flow rates will be monitored.

10.6 Toilets

Electric-or propane-fired toilets will be used at the camp and possibly at the dome drill site (Sections 8.1 and 12.4). Industrial safety standards for these toilets will be followed.

11.0 HELICOPTER OPERATIONS

Due to the remote location of the project, transport of personnel and materials must be accomplished by helicopter. Two types of helicopters are planned to support the project: large freight helicopters will be used primarily for mobilization and demobilization operations, and a small helicopter will be employed to support the day-to-day operations at the drill site. Larger freight helicopters will be sought to minimize the number of mobilization and demobilization flights. Helicopters supporting the operation will probably be required to maintain 2,000-ft altitude above the ground.

11.1 Helicopter Safety

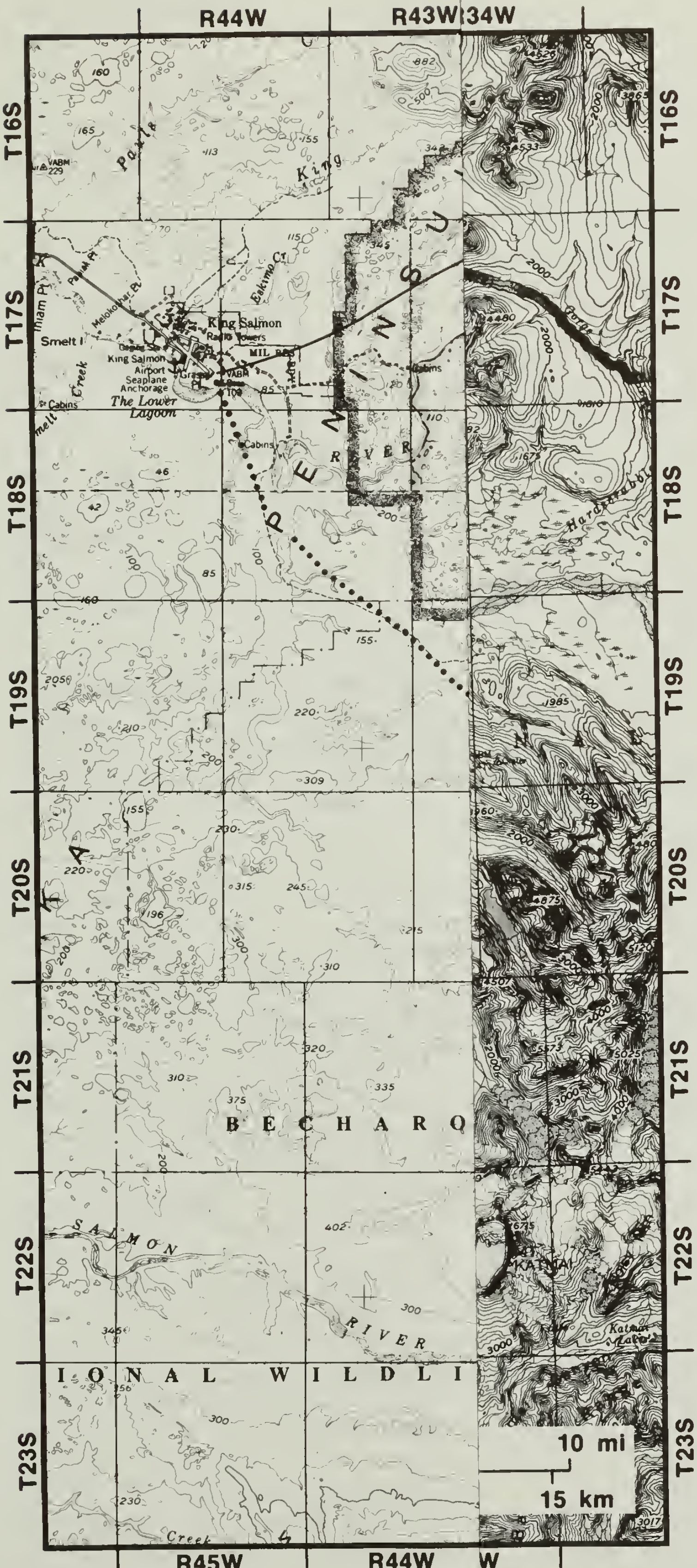
The Katmai project will conform with DOE/Albuquerque Operations Office Order 5480 1.3, "Aviation Operations and Safety (DOE/AL, 1990)." The appropriate regulations in the Aviation Manual of the Department of Interior (DOI) Office of Airline Services will be followed. Alaska helicopter firms will be sought because of the unique flying conditions in the Alaska bush.

Project helicopter safety and emergency procedures will be prepared by project personnel, the helicopter firm under contract, and DOI/DOE flight safety officers. All project personnel who work at the drill sites will learn these procedures before beginning the operation.

11.2 Proposed Helicopter Routes

Proposed helicopter routes (Figure 11-1) were chosen after discussion with personnel from the NPS, U.S. Fish and Wildlife (Becherof Wildlife Refuge, King Salmon; Ecological Services), Alaska State Fish and Game Division, (King Salmon), and the two largest Alaska-based helicopter companies. The helicopter routes are the following:

<u>Primary Route</u>	From King Salmon south of Lake Brooks (north or south of Mt. Kelez, depending on flight conditions) into the Valley of Ten Thousand Smokes, up Knife Creek or the River Lethe valley to the Novarupta Dome site.
Advantages	Most direct route. Time in air over the park (hence, intrusial) would be minimized.
Disadvantages	Overflies the road from Brooks Camp to Overlook Cabin. Tourists are in the area from 11:00 AM to 3:00 PM from June to September.
<u>Alternate Route 1</u>	Fly from King Salmon south to the King Salmon River system, up Angle Creek over the Windy River Drainage, over Butress Range into the Valley of Ten Thousand Smokes, and up Knife Creek to the Novarupta Dome site.
Advantages	Avoids tourists between Brooks Camp and Overlook Cabin.



Legend

········· Primary Helicopter Route

------- Alternate Helicopter Route 1

——— Alternate Helicopter Route 2

GTKat-42-0

Figure 11-1. Helicopter Routes

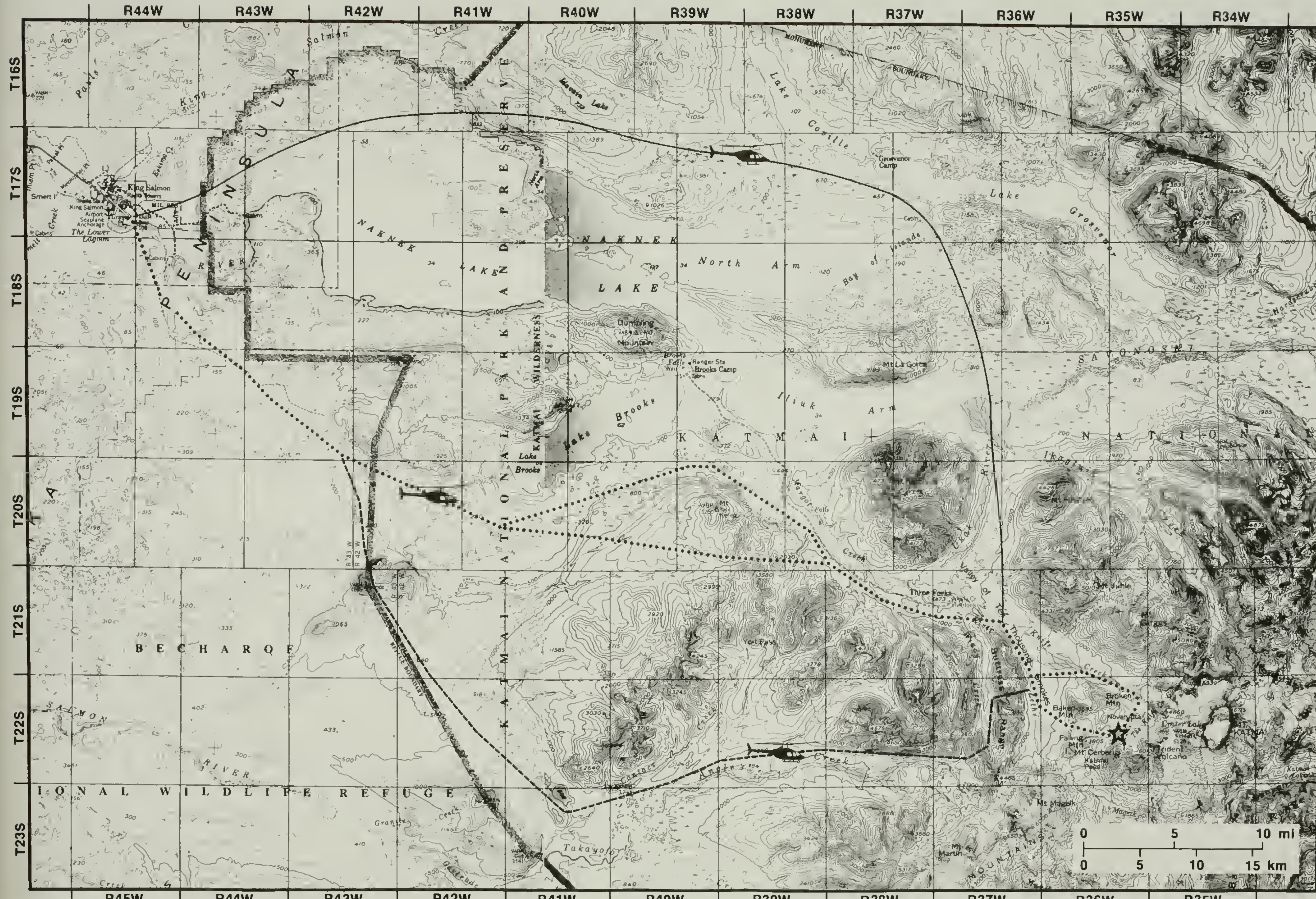


Figure 11-1. Helicopter Routes

Disadvantages	Must fly near the Aleutian Crest and over landforms approximately 2,800 ft high, between the Angle Creek and Windy River systems and over Butress Range. The weather around the mountains is often poor.
<u>Alternate Route 2</u>	Fly from King Salmon north of Naknek Lake, follow the south shore of Lake Coleville, then cross the lake to the Ukak River and into the Valley of Ten Thousand Smokes.
Advantages	A route away from Brooks Camp.
Disadvantages	Overflies routes used by many tourists in July and August.

In a life- or environment-threatening emergency, the helicopter will choose the most expeditious route and will notify the Drilling Site and NPS as soon as possible.

11.3 <u>Number of Flights</u>

The number of mobilization and demobilization flights will depend on the helicopter equipment available in Alaska at the time of the project. The largest helicopters have a freight-carrying capacity of approximately 22,000 lb. Other large freight helicopters have a freight-carrying capacity of approximately 7,500 lb. Smaller helicopters have freight-carrying capacities in the 1,000- to 3,000-lb range.

The smaller the helicopter used in the mobilization and demobilization, the more drilling and cementing equipment must be disassembled to be transported. For the proposed single mobilization, the weight of the material that must be lifted is approximately 1,200,000 lb, breaking down to approximately 1,100,000 lb of material for the vertical core hole at the dome site and approximately 100,000 lb of material for the ash-flow site. (There would be a minor demobilization after the first season and a minor mobilization in the second season, bringing in an additional 200,000 lb of additional material for the deviated hole at the dome site. Much of the material necessary for the deviated hole at the dome drill site [pad material, casing, etc.] is also necessary for the vertical hole. Because this material is intrinsic to the earlier hole to be drilled at the dome site, it is listed with the vertical hole).

The choice of helicopters for mobilization depends on cost, amount of material to be mobilized, and the flight path. The exact amount of freight that can be carried by a helicopter depends on the flight path. Helicopter freight-carrying estimates described below are for a flight path from King Salmon into the Valley of Ten Thousand Smokes with the helicopter pilots working a single shift. Mobilization with the largest freight helicopter (22,000 lb) could be accomplished in about a week. With a helicopter carrying 7,500 lb, mobilization could take approximately three to four weeks. Mobilization using a helicopter carrying approximately 2,500 lb would take about three months--an impractical situation. Thus, a larger helicopter must

be utilized for mobilization and demobilization. Estimates of mobilization and demobilization flights are given in Tables 11-1 and 11-2 for helicopters with a 22,000- or 7,500-lb freight-carrying capability. With only one large mobilization and demobilization rather than a multiphased operation, it may be economical to mobilize a large freight helicopter from Seattle or Portland if none are available in Alaska. For mobilization and demobilization, a Boeing Chinook, Aerospatiale Puma, or Boeing Vertol 107 helicopter are recommended.

A smaller helicopter would suffice to provide daily support for the operation. While no equipment has been chosen, an Aerospatiale Bl or Bell 212 helicopter has been under consideration for use as a support helicopter. The freight-carrying capacity of the Bl is from 1,250 to 1,650 lb; the Bell 212 is 2,450 lb. These support helicopters may average two to three round trips per day from King Salmon to the dome site, which is a total of 4 to 6 hr per day. During periods of intense activity, four or five trips per day may be necessary, which may necessitate the presence of two pilots. A minimum of three flights a day would be necessary between the camp and the ash-flow site: two flights for the two-shift-per-day crew changes and one for materials. The helicopters will carry in items for drilling (parts, tubulars, cement, drilling fluid additives, etc.) and carry out core and solid wastes in metallic containers.

Support helicopter flights out of the park will be at capacity if there is core or solid wastes from the operation to be carried out. About 160,000 lb of core will be park during the course of the operation. It may also be necessary to carry out a minimum of 50,000 lb of drilling waste out of the park. Personnel access will be accomplished by helicopter.

Earlier drilling operations in the Makushin Volcano on Unalaska Island, which began in 1983, utilized comparable support helicopter time for a comparably sized operation (Matlick, 1989).

11.4 Flying Conditions

Poor flying conditions are not uncommon in the Bristol Bay area. Table 11-3 gives the flight conditions in King Salmon in 1986 (Arment, 1989). These data include Visual Flight Regulations (VFR) flyable, marginally flyable, and not flyable weather conditions that were charted throughout the year from a fixed-wing plane flying from King Salmon to the east side of the Alaska Peninsula. These data suggest that fixed-wing flights are possible for approximately 30 percent of the time from King Salmon into the mountains on the east side of the peninsula. The weather on the east side of the peninsula is generally worse than the west side of the peninsula, where the Valley of Ten Thousand Smokes and the drill sites are located. Also, helicopters can sometimes fly under cloud cover when fixed-wing planes cannot. It is difficult to compare the experience of fixed-wing flights to the Alaska Peninsula with helicopter capability. Based on the experience of helicopter flights during recent geophysical studies, helicopter flights are possible from King Salmon to the mountains more than 50 percent of the time. This is based on summer and early fall operations.

Table 11-1

Estimated Helicopter Use During the Mobilization to Katmai*

Item	Total Weight to Katmai (lb)	Round Trip Capacity (lb)	Sling Efficiency	Round Trips	Round Trip Time (hr)	Total Air Time (hr)	Fuel Use Rate (gph)	Fuel Used (gal)
CHINOOK 234	1,200,000	22,100	0.85	64	1.45	93	425	40,000
VERTOL 107	1,200,000	7,475	0.85	184	1.67	315	170	54,000

*For the 4,000 ft Vertical Hole at the Dome and 660 ft Slant Hole at the Ash-Flow Site.

Table 11-2

Estimated Helicopter Use During the Demobilization From Katmai

Item	Total Weight to Katmai (lb)	Round Trip Capacity (lb)	Sling Efficiency	Round Trips	Round Trip Time (hr)	Total Air Time (hr)	Fuel Use Rate (gph)	Fuel Used (gal)
CHINOOK 234	560,000	22,100	0.80	32	1.45	46	425	19,500
VERTOL 107	560,000	7,475	0.80	94	1.67	156	170	26,500

Table 11-3

Aviation Data for Fixed-Wing Planes Flying in the King Salmon Vicinity in 1986 (VFR)

Month	Lowlands[2]			Mountain[3]			Total
	Flyable[4]	Not Flyable[5]	Marginal[6]	Fylable[4]	Not Flyable[5]	Marginal[6]	
January	16 (76%)	5 (24%)	0	5 (24%)	16 (76%)	0	21
February	10 (72%)	3 (21%)	1 (7%)	7 (50%)	6 (43%)	1 (7%)	14
March	12 (75%)	2 (12.5%)	2 (12.5%)	5 (31%)	7 (44%)	4 (25%)	16
April	12 (55%)	5 (23%)	5 (23%)	8 (36%)	13 (59%)	1 (5%)	22
May	17 (81%)	4 (19%)	0	10 (48%)	9 (43%)	2 (10%)	21
June	13 (62%)	3 (14%)	5 (24%)	5 (24%)	15 (71%)	1 (5%)	21
July	15 (68%)	5 (23%)	2 (9%)	8 (36%)	14 (64%)	0	22
August	15 (76%)	3 (14%)	2 (10%)	3 (14%)	14 (67%)	4 (19%)	21
September	17 (81%)	3 (14%)	1 (5%)	8 (38%)	12 (57%)	1 (5%)	21
October	16 (70%)	4 (17%)	3 (14%)	7 (30%)	15 (65%)	1 (4%)	23
November	6 (33%)	10 (56%)	2 (11%)	2 (11%)	15 (83%)	1 (6%)	18
December	10 (59%)	5 (29%)	2 (12%)	2 (12%)	14 (82%)	1 (6%)	17
Total	160 (68%)	52 (22%)	25 (11%)	70 (30%)	150 (63%)	17 (7%)	237
With Marginal Weather Resolved	178 (75%)	59 (25%)		78 (33%)	159 (67%)		
APPROXIMATE RATIOS	3:1			1:2			

[1]Weather checked at Flight Service Station twice each workday.
[2]West side of Alaska Peninsula (elevations of less than 500 ft).
[3]East side of Alaska Peninsula (elevations of more than 1000 ft).
[4]Y = Yes, flight can be made (VFR).
[5]N = No, flight cannot be made (VFR).
[6]M = Marginal weather, to take a "look."

12.0 FIELD CAMP OPERATIONS

12.1 Contents and Location of the Camp

The size of the field camp will be approximately 0.6 acres (Section 4.4). The field camp will support the drilling operations at the dome and ash-flow drilling sites and will be located next to the drill site at Novarupta Dome within the tephra ring. The field camp will consist of the following elements: office area, bath, kitchen and dining area, food storage, recreation area, 10 four-person sleeper tents, a core-processing facility, a medical and first aid tent, and potable water flow water treatment facilities.

The campsite is approximately 150 ft from the drill site and at least 12 ft in elevation higher than the drill pad. This is an important consideration for hydrogen sulfide safety (see Section 10.4). The campsite location within the tephra ring also provides partial shelter.

As mentioned in Chapter 4.0, the camp is in an area that rises gradually toward the tephra ring. Little earth-moving will be necessary to set the camp; silts or similar arrangements will be used. Walkways will be elevated and stairs to each of the tents may be necessary. The open area below floor levels of individual buildings can be used for utilities when necessary.

Fuel storage for the camp is combined with storage at the adjacent dome drill site and piped to the camp. Fuel lines and power serving the camp and running through the utility corridors will have absorbent pads at elbows and joints. The camp will have its own water, which will be stored in a tank or bladder. Water from the waterline will be filtered and treated. Water use at the camp will be approximately 1,200 gal per day.

Access inside the camp is limited to walkways. One helicopter pad at the dome site will serve both the drill site and campsite. Office space will also be shared with the drill site.

The number of permanent camp personnel will be minimized; only essential personnel will be onsite (Table 12-1). However, the number of personnel present must always be adequate for safe response to drilling or environmental problems. The camp will have sufficient space for itinerant operating personnel and official visitors in case of severe weather. The number of permanent site personnel is approximately 20. The number of itinerant operating personnel will probably average approximately 3.

During the three-to-four week period that the core hole at the ash-flow site is being drilled, the number of permanent camp personnel may increase by four of five. However, during periods of delays at the dome site (such as waiting for cement to harden or when the well is being logged), work can proceed at the ash-flow site with the crew from the dome drill site.

Table 12-1

List of Personnel and Types of Itinerant Occupants at the Field Camp

---

Field Personnel

1 Principal Investigator
2 GRDO Site Managers
1 USGS Site Manager (may also be the Principal Investigator)
1 Drilling foreman
6 drilling crew persons (two 3-person crews)
1 Drill rig mechanic/welder
3 Two waterpersons/helpers
3 Camp personnel
1 Park Ranger
1 Helicopter pilot
1 Helicopter mechanic
Emergency medical technician (may be a member of the crew)
1 Drilling fluid specialist

Itinerant Operating Personnel

2 to 3 cement crew persons
Contract inspectors
Special crafts
Inspectors from permitting agencies and environmental firms under contract

Other Itinerant

Science visitors (national and international)
Students
Visiting park tourists
Management from funding agencies

12.2 Access Between the Ash-Flow Drill Site and the Main Camp

The operations at the remote ash-flow drill site in the valley will be supported by the camp near the main site. Crew changes and supplies for this site will be accomplished by helicopter. A survival tent and emergency food supplies will also be placed at the remote ash-flow drill site. Weather periods can be severe enough to preclude ready access between the main campsite and the remote site; thus, the crew at the remote site may need to use the survival tent to obtain food and shelter.

12.3 Permanent and Itinerant Occupants of the Camp

The permanent camp personnel at the main site (Table 12-1) will consist of a drilling foreman, six drilling crew members, one welder/mechanic, three waterpersons, three camp personnel, two GRDO personnel and one USGS Site Manager, and one Principal Investigator (who may also be the USGS Site Manager). It is anticipated that a Park Ranger will be in residence. The ranger will specialize or be knowledgeable in areas of resource management, geology, and biology. The helicopter pilot and mechanic will remain either at the field camp or King Salmon, as safety requirements and operational conditions dictate. At the camp there will also be an emergency medical technician that could be a crew member. Safety requirements may necessitate the presence of a highly trained medical technician. A drilling fluids engineer will be necessary to treat returned drilling fluids, maintain fluid properties, and assist in controlling lost circulation. An environmental, health, and safety technician will be flown in for frequent inspections.

Provisions will be made for itinerant personnel (Table 12-1), such as the two to three person cementing crew, special technicians on short-term bases, inspectors from the NPS and other permitting agencies, and contract inspectors from independent environmental companies. Also, visiting scientists, students, and occasional official visitors from the funding agencies may be present. There could be additional people in camp during crew change time, but this would normally last only for a couple of hours. It is anticipated that visits by scientists, funding agencies, etc., would consist of day tours only, but weather conditions or other factors could dictate overnight stays.

Many park tourists coming upon such an operation would want a description of the operation and scientific goals. A procedure for conducting tours and providing site interpertations for park tourists at the drill sites will be developed with the NPS. Numerous safety questions must be resolved, including excluding tourists from the immediate location of the drilling and coring operation. The proposed activity is on public land and is government-funded. The GRDO strongly advocates accommodating tourists who desire information. Posters and other visual displays will be made available for the Park Office at King Salmon and at Brooks Camp.

12.4 Camp Waste and Bear-Proofing the Camp and Drill Sites

Because all human waste will be incinerated, it should not be necessary to construct a septic system at the camp. Wastewater from the camp in the form of grey water will be run through a grease trap and allowed to leach into the ground with the treated drilling fluid. An alternative to this is to construct a separate drain field for the camp in addition to the one for the treated drilling fluids. An engineer licensed in the State of Alaska will review and modify as necessary the drain field for the drill site and camp. Other solid materials will be compacted and flown out to an approved storage area.

The camp will be clean and bear-proof. Foods and edible trash will be stored in bear-proof containers. All necessary bear-proofing practices will

be conducted by camp personnel and adhered to by all personnel at the camp and both drill sites.

12.5 Park Access for Camp Personnel and Encounters With Animals

Access to parts of the park other than for project operations will be controlled by the NPS. Off-duty personnel will be subject to normal NPS permitting procedures for recreational trips within the park. The resident Park Ranger will manage encounters with animals.

13.0 SITE SUPPORT FROM THE KING SALMON-NAKNEK AREA

13.1 Mobilization by Barge and Dock Facilities

Much of the material for the operation's main mobilization may come from the Seattle area, Canada, and the Anchorage area. Materials will be shipped in a barge to the King Salmon-Naknek area. There are two scheduled barge lines into the Naknek: Pacific Alaska Line West and Northland Services. If necessary, arrangements can be made for docking facilities in the King Salmon-Naknek area either from the Bristol Bay Borough or from one of the local fishing camps. Scheduled barge service to the King Salmon-Naknek area is usually between the middle of April through the middle of October. A chartered barge or other vessel may operate in this area outside of these dates, depending on the weather. The material will be trucked to the support base at the King Salmon airport. The scheduled barge companies can arrange for the trucking of the material to the King Salmon airport.

13.2 Support Base at the King Salmon

A support facility will be set up in King Salmon to provide logistical support for the operation; some facilities will be located near the airport to facilitate use of the helicopters. For support, a storage area, forklifts, and other vehicles will be available, as well as personnel to help sling equipment for the helicopter. Long-term storage will be arranged.

Rental of a vacant building at the airport is envisioned. Contacts have been made with a contractor who owns such a building.

A technical expeditor will support the drilling and camp operations from this facility in King Salmon. It is possible that a relief drilling personnel will be in residence at King Salmon in proximity to this facility.

13.3 Logging and Disposition of Core from the Field, Through the King Salmon Support Base, to the USGS in Anchorage

The Curation Office develops a project-specific core- and sample-handling protocol and monitors compliance with this protocol. The Curation Office will provide training to the PIs and to the USGS geologists in the field. They will provide assistance in the field as needed. The wiping, marking, and initial inspection of the core will be handled in the field by the PIs. After this initial core inspection, it will be shipped by helicopter to the support facility at King Salmon.

The core will be further analyzed and logged as necessary at the support facility in King Salmon and prepared for shipment. It will be shipped to Anchorage for further logging and will be sampled for analyses. The core will then be documented by the Curation Office. Subsequent analyses will be conducted by the consortium of scientists and laboratories as described in the Katmai Science Plan. The remaining core will be sent to the Curation Office core facility at the DOE/United Nuclear facility in Grand Junction, Colorado.

14.0 OPERATING STANDARDS, ENVIRONMENTAL PROTECTION, SITE RECLAMATION, AND BENEFITS TO THE PARK

14.1 Statement of Operating Standards

The project will conform to all regulations required for the issuance of permits to conduct this operation. These include 36 CFR 9 and all orders issued by the Director of the Alaska Regional Office of the NPS, the Superintendent of Katmai National Park, or their agents. The project will conform to the appropriate Geothermal Regulations from Chapter 87 of the Alaska Register, as well as all other federal, state, and local laws and regulations. Any exceptions will be implemented only after specific requests for variances have been made and permission from the appropriate permitting agency has been received. Standards of the American Petroleum Institute will be adhered to where they are applicable to this mode of continuous coring. The operation will be conducted in a professional and safe manner. Professional standards will be upheld.

14.2 Policy for Environmental Protection

The project will attempt to prevent or mitigate any damage to the environment that can be found by the project group, the NPS, the State of Alaska, other permitting agencies, or the public during the operation. The project cannot guarantee that there will be no undiscovered damage to the environment anywhere in the park from the operation. However, if any such damage is found and is reasonably attributed to this drilling project after plugging and abandonment, a corrective effort shall be mounted.

The drill site and the campsite will be kept clean, and each aspect of the daily operation will be designed to minimize environmental impact. The campsite and drill site will be policed by designated individuals for loose debris, integrity of tanks and other storage areas, or for other factors that might effect the environment. Specific steps taken to protect the environment are listed in Chapter 10.0 and Section 14.4.

14.3 Policy for Site Restoration (Reclamation Plan)

All surface structures, equipment, remaining supplies, other manmade articles, and debris will be removed. The core holes will be plugged and capped below the surface and abandoned according to NPS and State of Alaska requirements. No material from the project will remain on the surface.

The drilling pad will be removed. Cement from the guy wire anchors will be removed to a reasonable depth, and the surfaces will be restored. Dikes and berms will be removed, and these areas will be restored and regraded to their previous contours. The paths used by the vehicle will be regraded. The waterline will be removed. The surface on the path between the camp and the adjoining main drill site and the surface adjacent to and along where the waterline lies will be restored.

Original surface contours will be restored, and the banked surface material will be reapplied to the surface, if possible. The utility vehicle and hand tools will be used to accomplish the reclamation work. The drill and

camp construction personnel will conduct the rehabilitation. Photographs and detailed topographic maps of the drill sites taken prior to construction will be used as a guide for the reclamation work. Reclamation costs will be included in the overall core hole and site abandonment costs.

14.4 Steps for Environmental Preservation

Every aspect of the daily operation will be designed to minimize environmental impact. The following reaffirms and summarizes measures to be taken to mitigate environmental impact:

- Helicopter flight routes were planned in consultation with the NPS, the U.S. Fish and Wildlife Service, the State of Alaska Fish and Game Department, and the helicopter company under contract.

- Photographs will be taken and topographic maps will be made before site excavation to assist in onsite restoration. A final set of pictures will also be taken after site restoration. Topographic maps will be made during the site restoration process. Photography will be accomplished in collaboration with NPS personnel.

- Excavation will be limited mainly to constructing berms with minor excavation in the area of the camp and in waterline pumping stations.

- Surface material will be banked for later use, if practical.

- Access to the camp from the drill site will be restricted to a designated pathway.

- Any necessary access across the moss and lichen or soft soil will be facilitated by decking material, planks, etc., and will be wide enough to allow easy walking and distribution of weight to minimize disturbance to the plant growth. If desired, vegetation transects will be established under NPS supervision to determine impacts to the site and recovery in later years.

- A policy for project personnel access to the park for recreational purposes, walking beyond the project area, will be planned with the NPS prior to the start of the operation.

- An organic liner such as polyethelene is planned for the lining of all berms with a layer of heavy geotextile material between the excavated pumice and the polyethelene liner. Extra lining material will be used at Lake Mageik.

- Storage areas for sensitive fluids will be lined, bermed, and covered. This area will be inspected for leakage on each shift.

- Solid drilling fluid additives and dewatered solids will be stored in a covered area.

- Sensitive material storage will be monitored.

- A grade-all or D3 or D4 wide-track caterpillar tractor for low-pressure footprint will be used to move equipment and materials and will be confined to the drill sites. The vehicle will be configured and used as a combination forklift, crane, and bulldozer. This vehicle is needed for minor excavation because the project will utilize heavier components than those ordinarily used in diamond coring operations. Use of such a vehicle would expedite the operation, would result in less time in the park, and would provide a means to effectively restore the area at the end of the operation.

- Arrangements are under way with a local municipality to place solid wastes, if any, in an approved waste site. If necessary, drilling solids can be fixed near or on the premises of the waste site. If local arrangements cannot be made, the solids and liquids will be temporarily stored in a safe manner for shipment to a proper site for environmentally safe disposal. Drilling solids would then be stored in an area permitted for such materials.

- The leaching fields from the drill site and camp will be combined. Drilling fluids will be treated before they are sent to the leach field. Camp fluids will be run through a grease trap.

- Electric or propane toilets will burn all human waste.

- All materials or solid wastes will be suitably packaged in proper containers for helicopter transport and waste site disposal. A compactor will be onsite to compact solid trash, as applicable.

- Absorbent pads will be put around machinery, valves, and other areas where fuel may seep. Drip pans will be under machinery where appropriate.

- Project personnel will be trained in spill prevention and control, first aid training, and CPR. Certain personnel will be trained in handling of hazardous materials. Drillers will receive blowout prevention training. Sensitivity to the esthetics of the park and wilderness will be emphasized throughout the training.

- Materials to combat a spill will be stored at the drill site and at the site support area in King Salmon.

- Independent contractors will inspect the operation for environmental compliance and for fuel, liquid, and solids handling. The independent contractor will also make site checks a year after site abandonment. The contractor will advise GRDO of any recommended remedial action.

- A contingency contract with an Alaska firm that will be established to mitigate, control, and clean up spills will be in place in the event that there is a spill of sensitive liquids requiring outside assistance to remedy.

- Solid drilling fluid additives will be stored out of the elements.

- A water storage tank will be available in the unlikely event of a blowout.

- Returned drilling fluids and solids will be sampled for analyses.

- An oil field service company with experience in geothermal cementing will be under contract to help ensure a good bonding of the conductor pipe and main casing string to the formation, and to help the project in combating severe lost circulation problems.

- Nearby streams, springs, and rivers will be monitored for contamination.

- Funds will be reserved to combat spills and mitigate any resulting damage.

- Solids will be removed from drilling fluids, and the fluids will be recycled. This will minimize the amount of returned drilling fluids and the volume of drilling wastes.

- Any project-related debris detected during the operational or post-operational inspection phases will be removed from the park. Attendant damage will be remediated. Existing debris that is unrelated to the project will be removed whenever possible.

- Both the helicopter and camp industries in Alaska have a history of successful environmental compliance. In addition, the environmental awareness of the diamond core (minerals) drilling and coring industry that will conduct this work has vastly increased in recent years. The project will consider environmental awareness as an important criteria for contractor selection.

- Before fielding, engineering will be performed by the project. Certain critical items, although satisfactory for use today, may be improved. The project does not depend on any invention or on the development of any item or product.

14.5 Benefits to the Park

The enabling legislation that established Katmai National Monument in 1912 and placed the region under the protection of the NPS stated that the Valley of Ten Thousand Smokes was to be the object of the scientific study of volcanic processes. The present proposal is responsive to this goal and employs the best, coordinated, interdisciplinary approach that current knowledge and technology permit. Because the eruption in 1912 was the central event that led to the establishment of Katmai National Park, the greatly improved understanding of the eruption which this project will provide will enrich the experience of visitors to the park. In particular, the third dimension of knowledge that is now lacking but which drilling will provide will convey a broad view that the phenomena observed at the surface, however spectacular, are only an expression of the powerful forces at work beneath the Earth's surface. The Visitor Center, Overlook Cabin, and other places in the valley will have available annually updated geological displays and

nontechnical literature that will reveal findings of this project. The project will develop this educational effort under the direction of the interpretive program of Katmai National Park.

Scientific results from the project will also contribute to the management of the park by the NPS. The region is volcanically active and is subject to the most dangerous type of eruption. Future eruptions are certain, and future eruptions of the Novarupta vent at the head of the valley are probable. Thorough knowledge of past eruptions, of which the eruption in 1912 is by far the outstanding occurrence, is the best guide to future decisions concerning closure of areas and emergency response procedure when new activity threatens.

As mentioned above, the project will support NPS needs, when possible, by removal of existing debris, particularly from the Baked Mountain Hut area. The intent will be to leave the park in better condition than when the project began through remediation of previous damage and scrupulous avoidance of new damage.

15.0 IMPACT TO FLORA AND FAUNA; CLIMATOLOGICAL, WATER FLOW, AND CULTURAL CONSIDERATIONS; AND ENVIRONMENTAL CONSEQUENCES

15.1 Flora

15.1.1 General Comments

There are two flora zones within the park: the Hudsonian and the Arctic zones (Cahalane, 1959). Site areas are predominantly in the Arctic zone due to elevation. The Arctic zone extends from the mountain tops down to approximately 2,000 ft. Lower elevations also have this Arctic zone where glaciers exert an influence. The dome site and camp have a 2,500-ft elevation. The ash-flow site has an approximate 1,850-ft elevation (Figures 1-3 and 4-2). Flora and fauna in the Arctic zones are relatively simple. They are especially simple in the Valley of Ten Thousand Smokes due to the devastation of the eruption in 1912. Low-lying plants and small mammals characterize much of the flora and fauna, although larger mammals occasionally pass through these areas. Exposed ridges in the park are depleted of snow during the winter, and available moisture to plants is reduced. Strong winds control the availability and potential for vegetation on this pumice-like material by diminishing moisture and blowing away soil that would form. Thus much of the existing flora that has reestablished itself since the eruption in 1912 is sheltered.

15.1.2 Flora Before the 1912 Eruption

Several small areas containing flora and fauna survived the eruption in a small canyon between Mt. Katmai and Mt. Juhle (Cahalane, 1959). These provide a clue to the preeruption vegetation and are summarized in Table 15-1. These sites are well provided with moisture.

15.1.3 Devastation From the 1912 Eruption

During the summer of 1917, Griggs stated that

> . . . all vestiges of life were consumed by fire . . . Throughout the upper portion of the Valley of Ten Thousand Smokes and its branches not a vestige of the vegetation which must once have covered it is to be found. So complete has been the destruction that no evidence of what happened to the plants remains to tell the tale . . . We could not reasonably suppose that the area had been devoid of all vegetation before the eruption. Indeed, we knew that there were once good-sized trees far up toward Katmai Pass. On the other hand, in the light of our acquaintance with conditions on the other side of the range, we were hesitant in hypothecating destructive agencies so intense as to eradicate the very evidence of their action (Griggs, 1919).

Flora and fauna had been totally destroyed by the 1912 eruption.

Table 15-1

Species of Flora Collected From Original Plant Colonies That Survived the 1912 Eruption

Schizogonium murale (green algae)
*Philonotis fontana (moss)
Equisetum arvense (common horsetail)
Agrostis scabra var. geminata (tickle grass)
Deschampsia caespitosa, tufted hair grass
*Stellaria crispa (crisp starwort)
*Cerastium caespitosum (larger mouse-ear chickweed)
Papaver radicatum subsp. alaskanum (Arctic poppy)
*Cardamine bellidifolia (alpine cress)
*Saxifraga punctata subsp. nelsoniana (brook saxifrage)
Geranium erianthum, northern geranium
*Heuchera glabra (alpine heuchera)
*Epilobium hornemannii (Hornemann willowherb)
E. latifolium (dwarf fireweed)
*Romanzoffia sitchensis (mist maid)

*Not seen elsewhere in valley as of 1953-1954.

15.1.4 Reestablishment of Flora

The first flora that returned to the valley was algae and mosses around the fumaroles, which were observed in 1917 but died out as the fumaroles cooled. Liverworts that had formed thick heavy carpets were observed in 1930 (Griggs, 1933). However, Griggs mentions isolated clumps of grass close to Novarupta Dome in 1930. Grasses are presently established just to the northwest of Novarupta Dome within the tephra ring. By 1954 the liverworts had disappeared and most of the active moss and algae had retreated to the remaining warm fumaroles. Steam that was so prevalent from the many fumaroles after the eruption was no longer available to permeate the tuff, and rainwater ran off the tuff and did not remain to nurture plants.

However, by 1954 higher plants had gained footholds on the ridges between Novarupta Dome and Mt. Juhle, particularly in local depressions or washes. An example of plants reestablishing in such a depression in the pumice is given in Figure 15-1. Plants observed up to that time are listed in Table 15-2.

Plots were established in the Valley of Ten Thousand Smokes to systematically study flora (Cahalane, 1959). Two plots were in the broad flat valley west of the Baked Mountain (Figures 4-2 and 4-3) draining to the River Lethe. These plots are similar to sites selected for the ash-flow site and the camp. Little or no vegetation at these sites was seen. One site was on the western slope of the tephra ring surrounding Novarupta Dome. Flora was largely confined to washes.

GTKat-28-3

Figure 15-1. Reestablishment of Flora in Gullies in the Valley of Ten Thousand Smokes

Table 15-2

Flora Observed in the Valley of Ten Thousand Smokes in 1953 and 1954

Pogonatum alpinum (alpine pogonatum)
Polytrichum commune (hair-cap moss)
P. juniperinum (juniper hair-cap moss)
Equisetum arvense (common horsetail), 5 localities
Agrostis scabra (tickle grass)
A. scabra var. geminata (tickle grass), 2 localities
Calamagrostis canadensis (bluejoint), 5 localities
Deschampsia caespitosa (tufted hair grass)
Trisetum spicatum (downy oat grass), 2 localities
Poa arctica subsp. williamsii (Arctic blue grass), 5 localities
P. hispidula (hispid blue grass), 2 localities
P. lanata (lanate blue grass)
P. stenantha (narrow-flowered blue grass)
Eriophorum angustifolium (tall cotton grass)
E. scheuchzeri (white cotton grass)
Carex macrochaeta (Alaska long-awned sedge), 2 localities
C. mertensii (Mertens sedge), 8 localities
Luzula arcuata (alpine wood rush), 3 localities
L. parviflora (small-flowered wood rush), 2 localities
Salix alaxensis (felty-leaved willow), 4 localities
S. anglorum (willow), 2 localities
S. arbusculiodes var. glabra (willow)
S. arctica (Arctic willow), 2 localities
S. arctica var. obcordata (Arctic willow)
S. barclayi (Barclay's willow), 3 localities
S. desertorum (willow)
S. geyeriana (willow)
S. pseudomonticola (willow)
S. pulchra (beautiful willow)
S. scouleriana (willow)
Oxyria digyna (mountain sorrel), 4 localities
Sagina intermedia (snow pearlwort)
Papaver radicatum subsp. alaskanum (Arctic poppy), 2 localities
Oxytropis (sp. ?) (oxytrope)
Epilobium latifolium (dwarf fireweed), 4 localities

15.1.5 Sheltered Areas and Current Flora

There is no soil (as commonly defined) on these deposits or forest in the area. Sparse grasses, mosses, small plants, and trees are returning. These plants live mainly, but not exclusively, in thermal areas around Novarupta Dome and in other sheltered areas. This is especially true northwest of the dome within the tephra ring. There are grasses, numerous plants, and moss. Water from rainfall remains there longer than over the other reworked pumice surfaces nearby.

Numerous soft surfaces containing lichens and moss are present in the vent region and on the outer slopes of the tephra ring (Chapter 4.0). If the moss must be removed, attempts will be made to bank it for reapplication later, if feasible.

Moss and lichen (cryptogams) is the first stage in the normal process of establishing flora in the areas laid bare by the 1912 eruption. Moss and lichen stabilizes the soil, adds organic matter to the soil, and increases the moisture content of the top inch of the soil. This further stabilization of the soil may assist in the colonization of higher forms of flora mentioned above.

The sites proposed for the drill sites and camp have mainly bare pumice that may have been reworked by wind and water (Section 4.1). There is little or no vegetation at these sites, which is consistent with the earlier vegetation studies. There is flora in the proximity of the dome drill site and mosses in the vicinity of the access path between the dome site and the camp. Efforts were made to avoid vegetated areas in site selection.

15.2 <u>Fauna</u>

15.2.1 Birds

Bird life in the area before the 1912 eruption was eliminated by the eruption. The resulting inhospitable environment prevented most species from returning to the Valley of Ten Thousand Smokes, and sightings of birds in the Valley is still uncommon. Table 15-3 lists observations of birds and their location in the valley.

There is little potential bird habitat at either the ash-flow site or the camp. However, snow buntings reside in the area around Novarupta Dome in the summer. Waterfowl do not inhabit the area near the drill or sites.

The area around King Salmon airport is inhabited by waterfowl in the spring and fall seasons (Figure 15-2); flying in higher altitude mitigates this potential problem.

Table 15-4 lists the results of a waterfowl survey conducted during the months of April and May along the Naknek River that runs adjacent to King Salmon. Table 15-4 shows results of the survey from 1983 (U.S. Fish and Wildlife Service, 1991).

15.2.2 Mammals

Small burrowing animals live in some of the thermal areas around the dome. These animals now inhabit the islands of vegetation discussed above. Bears and possibly moose and caribou pass through the valley, but their incursions are rare. The habitat in the valley is not hospitable to these animals.

Table 15-3

Observations of Birds Seen in the Valley of Ten Thousand Smokes Through 1954 (Cahalane, 1959)

Name	Place	Date
Green-winged teal	Seen at the head of the River Lethe valley	Mid-August, 1954.
American rough-legged hawk	Seen near Three Forks (lower valley)	September 14-17, 1940.
Golden eagle	Seen on the West slope of Katmai Volcano	July 4, 1954.
Northern bald eagle	Seen over the valley	Summer, 1917.
Marsh hawk	Seen at the lower end of valley	September 15, 1940.
Willow ptarmigan	Seen at the Upper Knife Creek	Early August, 1954.
Northern common raven	Seen at the Upper Knife Creek	August 15, 1954.
Western water pipit	Seen at the Upper Knife Creek	August 5, 1954.
Common redpoll	Seen over the valley	Summer, 1917.
Golden-crowned sparrow	Seen at the Head of Knife Creek	Early August, 1953.
Eastern snow bunting	Seen in the Valley and at the head of Knife Creek	Summer of 1917, and numerous occasions in July and August, 1953 and 1954. Seen regularly in the vicinity of Novarupta Dome.

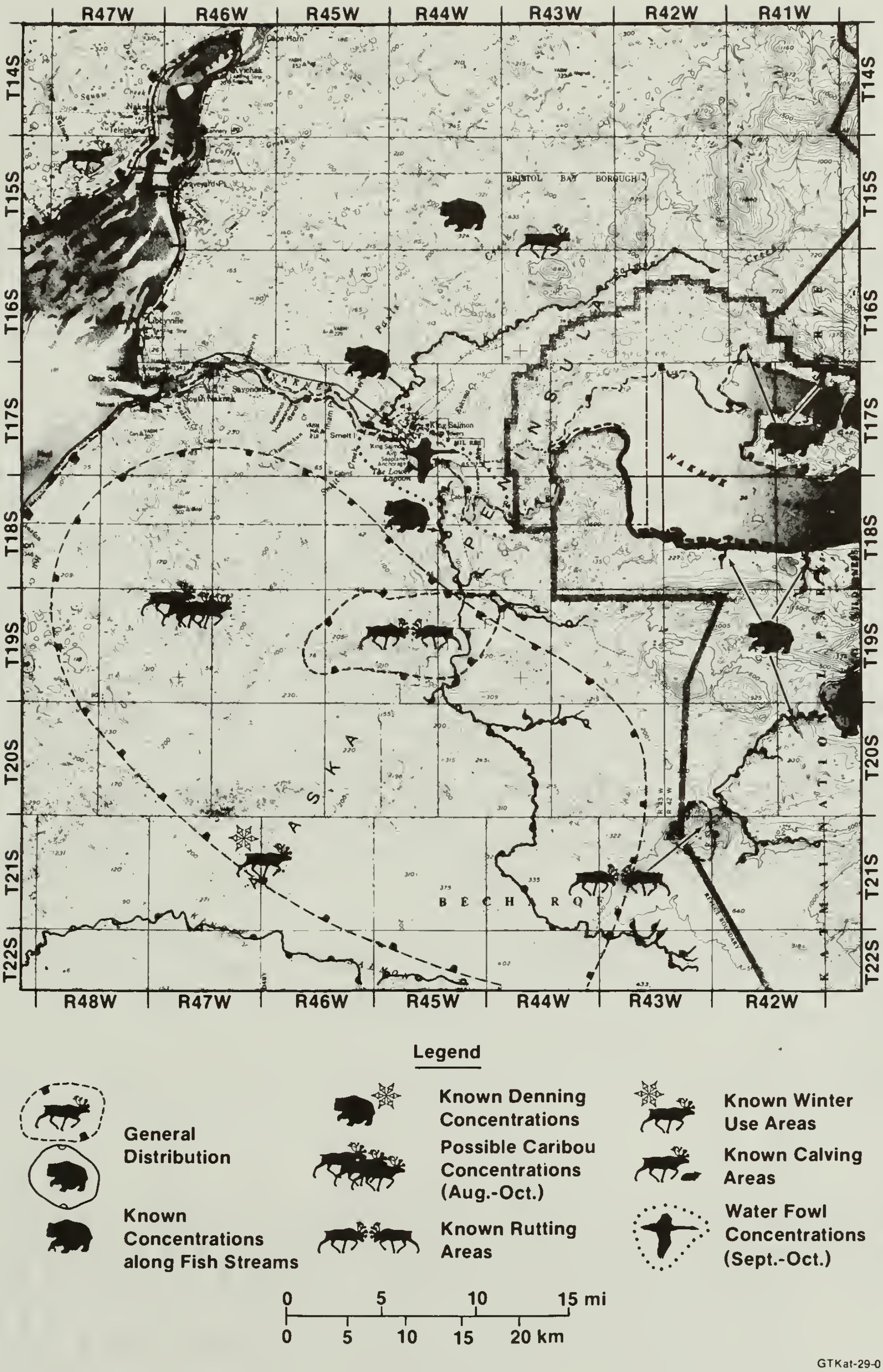


Figure 15-2. Bear and Caribou Use Areas and the Area Inhabited by Waterfowl in the Vicinity of Naknek River

Table 15-4

Highest Recorded Abundance of Waterfowl by Species for Each Year From Aerial and Ground Surveys on the Naknek River, Alaska Peninsula, Alaska

	1983	1984	1985	1986		1987	1988	1991	
Species	A[a]	A	A	A	G[b]	A	A	A	G
Tundra Swan	720	2625	2776	1965	1145	2903	1970	2379	1544
Gr. white-fronted goose	63	2453	1610	1129	758	309	124	277	252
Emperor goose						1			
Brant			1						4
Canada goose	40	182	846	234	52	21	68	38	34
Green-winged teal	7		13		114			47	32
Mallard	280	600	263	650	44	621	199	539	252
Nothern pintail	640		1638	1319	1704	988	5573	3983	5183
Northern shoveler	2			150	75			4	38
Gadwall			25		4				2
Eurasian wigeon					3	4			6
American wigeon	354	30	375		35	52	9	161	206
Canvasback				3				6	11
Redhead				2	1				
Greater scaup	142		17	150	53	32	139	156	193
Common eider									75
King eider									5000
Harlequin duck									6
Oldsquaw	2		2	4		1		9	410
Black scoter				50		1	3	20	357
White-winged scoter				20		5			25
Surf scoter Scoter spp.	42		2						6
Bufflehead		25			1	4		3	11
Common goldeneye	315	1102	733		171	82	66	265	285
Barrow's goldeneye									2
Common merganser					199			1552	886
Red-breasted merganser					3			833	228
Merganser spp.	2075	1558	1644	1126		771	908		

[a]A=Aerial surveys.
[b]G=Ground survey.

The specific pattern of land use of mammals and other animals may vary over time. Usage pattern data for areas near potential helicopter flight routes can be made, however, from existing knowledge of state and federal fish and game agencies (State of Alaska, 1985; U.S. Fish and Wildlife Service, 1989; 1990; 1991).

In the warm season there are concentrations of bears along fish streams within an approximate 7- to 10-mi circle around Brook Camp. There are known concentrations of bears along fish streams in the vicinity of King Salmon. Bear dens are in the vicinity of Mt. Katolinat, Mt. Ikaghluik, Mt. Juhle, the Butress range, the Aleutian mountain range, and on the Shelikof Strait coast from the Katmai River to Kninak Bay (Figures 15-2 and 15-3). Denning is approximately in late October through mid-December. Some bears are active all year long.

Caribou concentrations of the Southern Alaska Peninsula (Malchatna) herd have been found south of the Naknek River (Figures 15-2, 15-3, and 15-4) where rutting and winter use areas are known. They are distributed along both sides of the Naknek River, Lake Brooks, Naknek Lake, and both east and west of the Valley of Ten Thousand Smokes. Both the southern and northern Alaska Peninsula herds have intermingled between the Naknek River and Iliamna Lake, although the calving grounds of these respective herds are far from the proposed drill sites (Figure 15-4) (U.S. Fish and Wildlife Service, 1989). Calving is from mid-May through the first week in June. During 1989, for the first time calving was documented in the hills between King Salmon Creek and the Alagnak River, which is 3 to 5 mi away from one of the alternate helicopter flight paths. Calving in smaller numbers was recently seen on the other side of King Salmon Creek (Russell, 1992). Caribeau migration and habitat is continually changing. Continuous contact will be maintained with State of Alaska and U.S. Fish and Wildlife personnel to track these changes. Helicopter routes can be chosen to avoid heavy animal use areas, and they can fly sufficiently high to minimize disturbance to these animals.

A general distribution of moose inhabit the areas between King Salmon and the Valley of Ten Thousand Smokes (Figure 15-5 and 15-6). There are no moose in the valley itself, though the general use area only encompasses the Novarupta Dome area. (Sightings of moose over any of the volcanic material are quite rare, however.) Calving is from late May into early June. Precautions taken to avoid disturbing bear and caribou will be adequate to avoid disturbing the moose population.

15.2.3 Fish

The rivers and streams in the Valley of Ten Thousand Smokes are not inhabited by fish. Salmon are present 2 to 3 mi up the Ukak River from Brooks Lake. Trout are seen 2 to 3 mi up Margot Creek from Brooks Lake.

15.3 Noise and Air Quality

The primary source of noise in the area is wind. During fair weather in summer, there are numerous sightseeing flights by light aircraft. Several of the neighboring Aleutian Range volcanic vents are sources of air pollution.

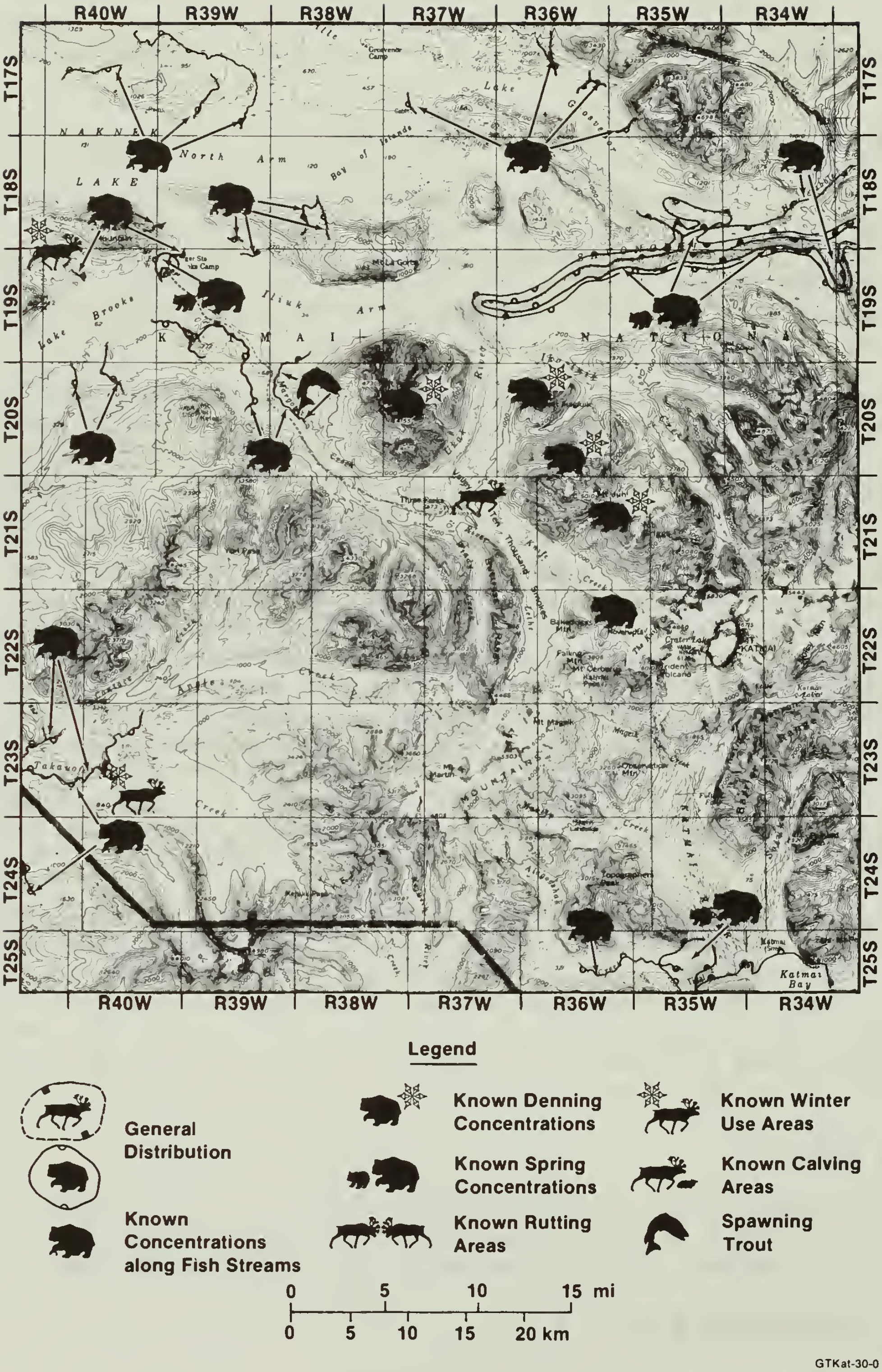


Figure 15-3. Bear and Caribou Use Areas in the Vicinity of Katmai National Park

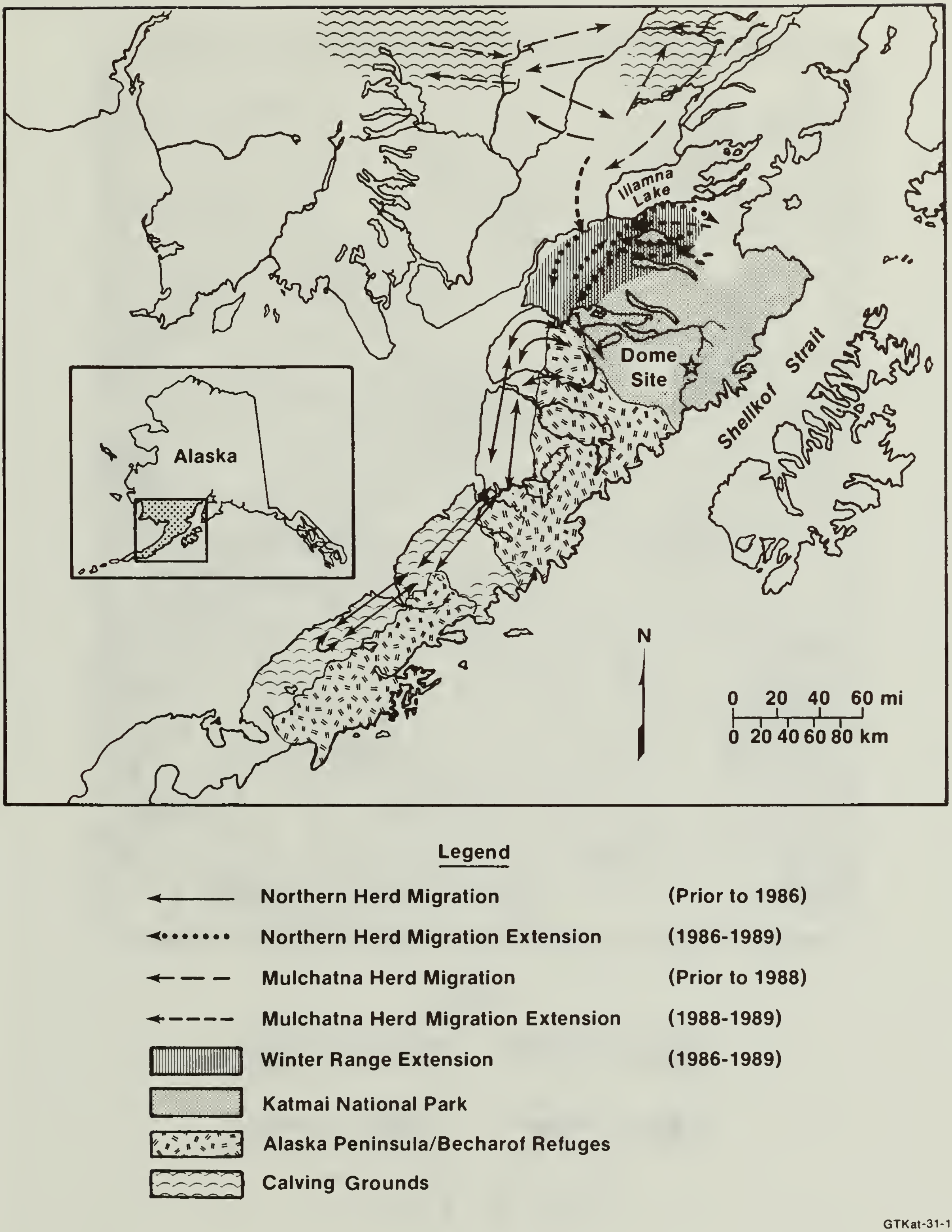


Figure 15-4. Principal Caribou Migration Paths, Range, and Calving Areas on the Alaska Peninsula

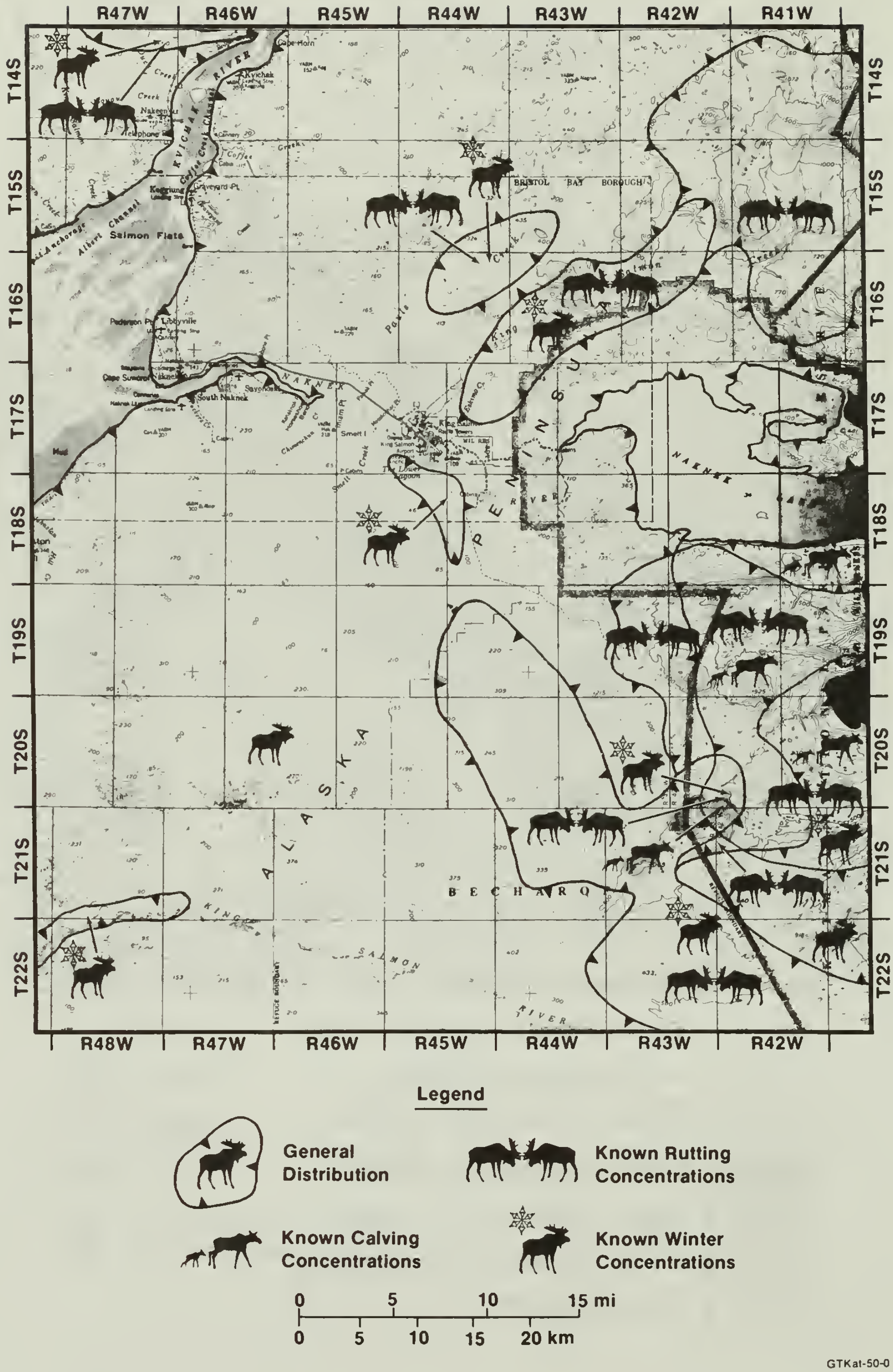


Figure 15-5. Moose Use Areas in the Vicinity of Naknek River

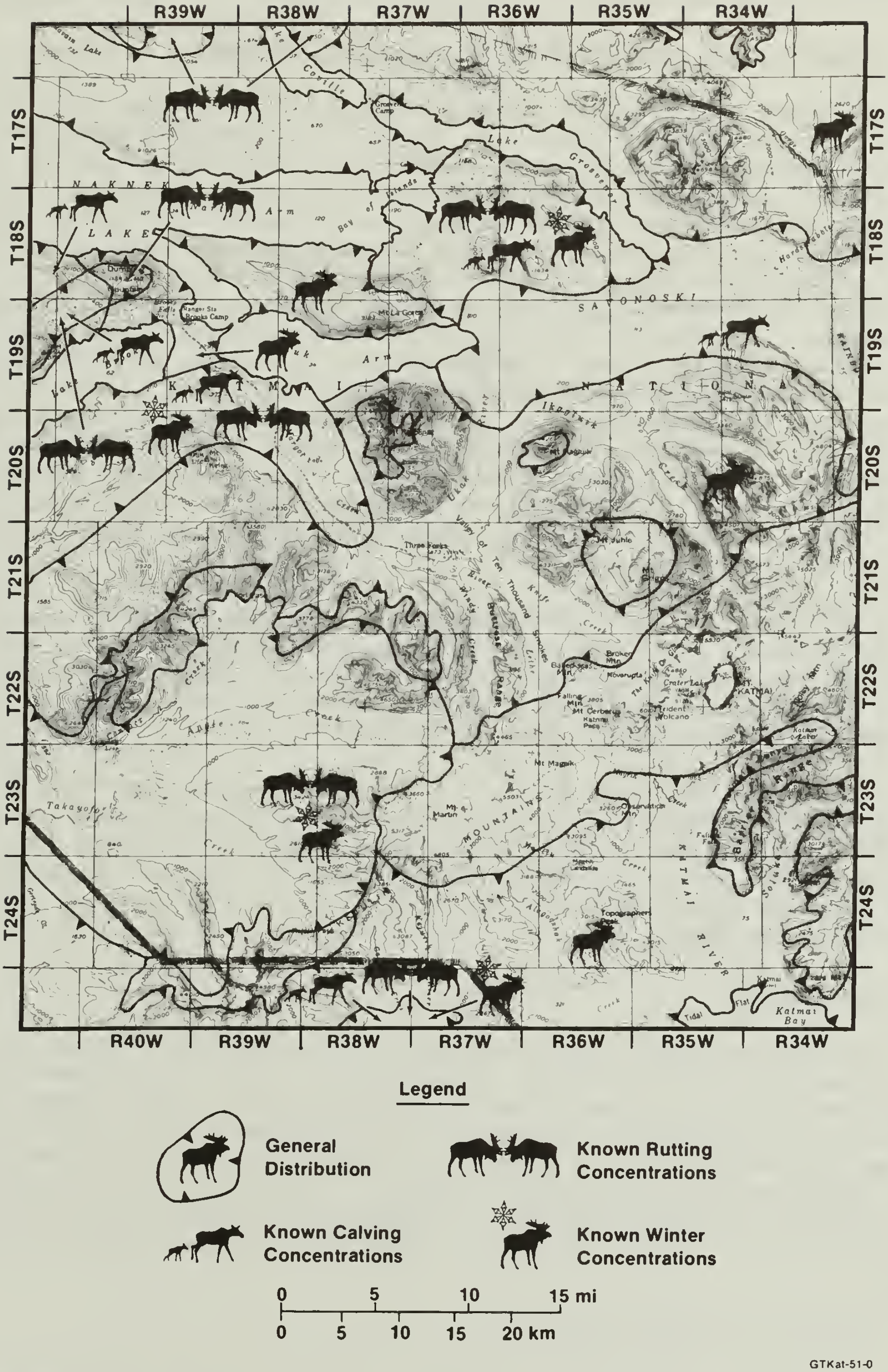


Figure 15-6. Moose Use Areas in the Vicinity of Katmai National Park

When the wind is from the southeast, a strong sulfur smell is evident in the Novarupta vent region from the recently active vent of Trident Volcano.

15.4 Climatological Data at King Salmon and the Proposed Drill Sites

The climate is cool and wet with limited diurnal variation. The area is subject to fog and strong winds. No weather data at the proposed drill sites has been recorded because of their remoteness. However, permission may be requested to record temperatures at nearby USGS Seismic Stations.) King Salmon and (to a somewhat lesser extent) the proposed drill sites undergo a predominantly marine climate with diurnal and seasonal temperatures confined within rather narrow limits. However, both King Salmon and the drill sites have definite continental influences causing occasional strong climatic fluctuations. From December through March (months of the proposed winter shutdown) the area undergoes strong winds due to passage of Aleutian lows. Winds of 50 to 90 mph are not uncommon in the King Salmon area. Strong winds are notorious in the mountains. Ice in the bay around King Salmon becomes safe to cross on foot in mid-November. The Naknek River ice becomes safe to cross on foot in approximately late November. Ice breakup on the bay is in early April, and on the Naknek River ice breakup is in approximately mid-April (NOAA, 1986). Possible months of barge transportation would then range from approximately April into October.

King Salmon and Kodiak climatological data are given in Tables 15-5 and 15-6 and Figure 15-7. These data verifies the tenuous nature of Bristol Bay Flight weather. For example, the mean cloud cover ranges from 60 to 90 percent in any given month and often the ceiling is low, consistent with tabulated flight conditions shown in Table 11-4.

The data in Tables 15-5 and 15-6 are only an approximation of the weather at the proposed drill sites. Cloud and wind conditions can be quite different from that of the King Salmon area. Due to elevation, the temperatures can be 10 to 20°F colder. Maximum snow on the ground at King Salmon averages approximately 10 in. Considerably more snow can be expected at the Novarupta Dome site.

15.5 Water Flow

Much of the fresh flow is thought to be subsurface flow through the porous tephra deposits from the 1912 eruption and above the Naknek siltstone. Fresh water springs flow more readily in rainy years. Water sampled over the duration of a decade from the Valley of Ten Thousand Smokes shows that saline warm springs and leaching of pumice add to the salt content of the River Lethe, Knife Creek, and Ukak River system. This system can be laden with silt, ash, and pumice. Fish do not inhabit this system except for the extreme lower Ukak River. The habitat in the valley is not hospitable to these animals.

15.6 Cultural Considerations

Any evidence of cultural activities before to the 1912 eruption is buried under a substantial amount of tephra, estimated to be hundreds of feet thick in the vicinity of the operation. A description of cultural resources

and social, economic, and environmental consequences will be detailed in the EIS.

Table 15-5

Local King Salmon Climatological Data Providing 10- and 20-Yr Averages

PREPARED BY: USAFETAC AUGUST 1983 | STATION NAME: KING SALMON AFS AK | LOCATION : N58 41 W156 39 | PERIOD: JUNE 42-DEC 82 | ELEV: 57 FT | STN LTRS: AKN | MSC NO: 703260

AWS CLIMATIC BRIEF

MONTH	TEMPERATURE (°F) MEAN DAILY MAX	TEMPERATURE (°F) MEAN DAILY MIN	TEMPERATURE (°F) MEAN MONTHLY	TEMPERATURE (°F) EXTREME MAX	TEMPERATURE (°F) EXTREME MIN	PRECIPITATION (IN) MONTHLY MEAN	PRECIPITATION (IN) MONTHLY MAX	PRECIPITATION (IN) MONTHLY MIN	PRECIPITATION (IN) MAX 24 HRS	SNOWFALL (IN) MONTHLY MEAN	SNOWFALL (IN) MONTHLY MAX	SNOWFALL (IN) MAX 24 HRS	MEAN RELATIVE HUMIDITY (%) LST 04	MEAN RELATIVE HUMIDITY (%) LST 13	MEAN VAPOR PRESSURE (IN Hg)	MEAN DEW PT (°F)	PRESSURE ALTITUDE (FT) 99.95%	SURFACE WINDS PVLG DRCTN (16 PT)	SURFACE WINDS SPEED MEAN (KT)	SURFACE WINDS SPEED MAX (KT) **	MEAN CLOUD COVER (?)	PRECIP (IN) ≥ 0.01	PRECIP (IN) ≥ 0.5	SNOWFALL (IN) ≥ 0.1	SNOWFALL (IN) ≥ 1.5	THUNDER STORMS	FOG VSBY < 7 MI	TEMPERATURE (°F) MAX ≥ 70	TEMPERATURE (°F) MAX ≥ 60	TEMPERATURE (°F) MIN ≤ 32	TEMPERATURE (°F) MIN ≤ -15
JAN	21	6	13	53	-46	1.1	3.0	.2	.9	7	19	9	75	73	.08	12	1750	N	9	70	7	10	s	7	2	0	9	0	0	28	5
FEB	23	7	15	51	-41	.9	2.8	.1	1.3	7	15	8	71	65	.06	7	1700	N	9	821	6	10	s	7	1	0	7	0	0	26	4
MAR	28	12	20	56	-42	1.2	2.4	s	1.0	8	20	11	78	66	.09	16	1350	E	9	80	7	11	s	9	2	0	9	0	0	28	2
APR	39	23	31	65	-19	1.0	3.0	s	1.2	5	16	5	31	61	.13	24	1300	E	9	62	8	10	s	6	1	0	9	0	s	26	s
MAY	51	34	43	77	4	1.1	2.4	.1	1.0	1	6	2	83	56	.19	33	1100	E	10	67	8	11	s	1	s	s	s	s	4	11	0
JUN	59	41	50	88	29	1.6	3.8	.3	.9	s	1	1	89	61	.26	41	800	S	9	60	9	13	s	s	0	s	13	2	13	1	0
JUL	63	46	55	86	30	2.1	4.3	.3	1.1	0	0	0	90	64	.32	47	650	S	9	65	9	15	1	0	0	s	17	6	20	s	0
AUG	61	47	54	84	28	3.2	6.4	1.1	1.4	0	0	0	89	66	.32	47	850	S	8	57	8	18	1	0	0	s	19	3	18	s	0
SEP	55	40	47	74	16	2.9	7.3	.9	1.7	s	1	1	86	66	.25	40	1200	SSE	9	64	8	16	1	s	0	s	12	s	5	5	0
OCT	41	26	34	67	-11	2.1	6.5	.2	1.3	3	15	5	82	69	.15	27	1550	N	9	65	8	14	1	3	1	s	10	0	s	21	0
NOV	30	15	23	50	-26	1.4	3.0	s	1.0	6	16	9	80	75	.10	18	1700	N	9	72	7	12	s	7	1	s	11	0	0	26	s
DEC	20	4	12	48	-38	1.2	3.7	.1	.8	9	16	6	75	73	.06	8	1900	N	8	62	7	12	s	9	2	s	11	0	0	29	5
ANN	41	25	33	88	-46	19.8	7.3	s	1.7	46	20	11	82	66	.15	27	1400	N	9	323	8	152	4	49	10	s	135	11	60	201	16
EYR	41	41	41	41	41	40	40	40	40	40	37	37	10	10	10	10	10	10	10	30	10	40	40	37	37	37	37	41	41	41	41

*Data are not available.
sAmounts are less than is shown in the heading.
**Instantaneous peak winds.
$Percentage of calm is greater than the percentage of PLVG direction.
Based on less than full months.

REMARKS: RUSSWO POR:
HOURLY OBS: JAN 73 - DEC 82
DAILY OBS: JUN 42 - DEC 82

Table 15-5 (Concluded)

Local King Salmon Climatological Data Providing 10- and 20-Yr Averages

CAV FREQ(%)	HRS LST	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	EYR
	00-02	22	17	24	27	21	32	34	34	19	24	21	26	25	
	03-05	22	17	25	31	25	41	44	43	20	25	23	23	28	
CEILING LESS	06-08	22	19	24	30	23	42	42	41	21	25	26	25	28	
THAN 3000 FT	09-11	21	19	24	28	23	36	38	36	23	26	22	24	27	
AND/OR VISIBILITY	12-14	16	17	25	26	22	25	29	30	20	29	24	23	24	
LESS THAN 3 MI	15-17	18	17	20	22	19	20	22	27	14	24	25	26	21	
	18-20	19	16	21	19	15	21	20	25	14	22	24	27	20	
	21-23	20	17	22	24	18	25	25	25	16	24	23	26	22	
	ALL HRS	20	17	23	26	21	30	32	33	18	25	24	25	25	10
	00-02	13	11	14	15	13	22	26	25	10	11	14	17	16	
	03-05	13	10	15	19	17	31	36	33	11	12	16	16	19	
CEILING LESS	06-08	12	11	16	18	15	33	34	32	12	13	16	16	19	
THAN 1500 FT	09-11	13	11	15	15	9	22	26	22	11	12	13	17	16	
AND/OR VISIBILITY	12-14	11	11	13	11	6	10	13	14	7	12	14	16	12	
LESS THAN 3 MI	15-17	11	11	12	8	4	7	8	10	4	9	15	17	10	
	18-20	13	9	13	9	6	8	8	12	5	8	14	17	10	
	21-23	13	10	12	11	10	16	14	16	6	10	15	15	12	
	ALL HRS	12	11	14	13	10	19	21	21	8	11	15	16	14	10
	00-02	10	8	9	11	10	20	22	20	8	7	11	13	12	
	03-05	10	8	8	14	14	29	32	29	8	10	11	12	15	
CEILING LESS	06-08	9	7	9	14	12	29	29	28	9	9	11	12	15	
THAN 1000 FT	09-11	10	8	10	9	6	13	17	15	6	s	10	13	10	
AND/OR VISIBILITY	12-14	9	9	9	6	3	4	5	5	4	s	10	13	7	
LESS THAN 2 MI	15-17	8	8	8	4	2	3	3	2	2	4	11	14	6	
	18-20	10	5	7	5	3	5	3	6	3	5	11	12	6	
	21-23	10	6	8	8	6	13	11	11	5	6	10	12	9	
	ALL HRS	10	7	9	9	7	15	15	15	6	7	11	13	10	10
	00-02	3	2	s	1	2	5	4	6	3	1	3	2	3	
	03-05	2	1	1	2	3	7	9	10	3	2	3	1	4	
CEILING LESS	06-08	2	1	1	2	1	2	5	8	3	2	2	1	3	
THAN 200 FT	09-11	1	1	s	s	s	0	s	s	1	1	2	3	1	
AND/OR VISIBILITY	12-14	1	2	s	0	s	0	0	0	0	s	1	1	s	
LESS THAN 1/2 MI	15-17	2	1	s	0	0	0	0	0	0	s	1	2	1	
	18-20	2	1	s	s	0	0	0	0	0	s	1	1	s	
	21-23	2	1	1	1	s	1	2	s	1	s	1	2	1	
	ALL HRS	2	1	s	1	1	2	3	3	1	1	2	2	2	10

*Data are not available.
sAmounts are les than is shown in the heading.
**Instantaneous peak winds.
$Percentage of calm is greater than the percentage of PLG direction.
Based on less than full months.

REMARKS: RUSSWO POR:
HOURLY OBS: JAN 73 - DEC 82
DAILY OBS: JUN 42 - DEC 82

Table 15-6

Local Kodiak Climatological Data Providing 10- and 20-Yr Averages

AWS CLIMATIC BRIEF

Prepared by ETAC (AUG 1971)

KODIAK NS, ALASKA
N 57 45 W 152 29

PERIOD: 1946-69
ELEVATION: 81 FT

WBAN # 25501
WMO # 70350
STN LTRS: (NHB) (PANH)

MONTH	TEMPERATURE (°F) EXTREME MAXIMUM	MEAN DAILY MAXIMUM	MEAN DAILY MINIMUM	EXTREME MINIMUM	PRECIPITATION (in) MEAN TOTAL	MAXIMUM IN 24 HOURS	MEAN SNOWFALL	MAX SNOWFALL IN 24 HOURS	WIND (KT) PREVAILING DIRECTION	MEAN SPEED	EXTREME SPEED (PEAK GUST)	MEAN RELATIVE HUMIDITY (%) 0400	1300	DEW POINT (°F)	VAPOR PRESSURE (in HG)	PRESSURE ALTITUDE 99.95% (Feet)
JAN	54	34	26	-5	4.7	3.2	13	11	NW	11	99	79	76	24	.13	1800
FEB	56	35	26	0	4.4	3.6	15	10	NW	10	86	79	76	24	.13	1650
MAR	57	36	27	-1	3.9	1.8	17	18	NW	10	73	78	72	24	.13	1500
APR	64	42	32	11	3.3	1.7	7	11	NW	10	84	78	69	29	.16	1500
MAY	80	47	38	20	4.3	1.9	#	4	E	8	53	83	73	36	.21	1000
JUN	86	54	45	30	4.2	2.3	#	#	E	7	61	85	76	43	.28	850
JUL	82	59	49	37	3.4	2.5	0	0	E	6	65	87	76	48	.34	650
AUG	83	60	50	36	4.3	2.2	0	0	NW	6	52	87	75	49	.35	900
SEP	71	54	45	26	6.1	2.6	#	#	NW	8	63	85	75	44	.29	1350
OCT	61	45	36	14	6.0	2.5	2	9	NW	9	72	81	71	34	.20	1700
NOV	54	39	31	6	5.6	2.3	5	14	NW	11	92	80	75	29	.16	1750
DEC	54	34	26	0	4.9	2.0	12	9	NW	11	97	76	75	23	.12	1850
ANN	86	45	36	-5	55.1	3.6	71	18	NW	9	99	82	74	34	.20	1500
EYR	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24

MEAN NUMBER OF DAYS

MONTH	PRECIP ≥0.01 in	PRECIP ≥0.5 in	SNOWFALL ≥0.1 in	SNOWFALL ≥1.5 in	THUNDER-STORMS	FOG (<7 MILES)	TEMPERATURE (°F) MAXIMUM ≥ 90	MAXIMUM ≤ 80	MINIMUM ≥ 32	MINIMUM ≥ 0	MEAN CLOUDS (TENTHS)
JAN	16	3	7	3	0	8	0	0	23	#	7
FEB	15	2	8	3	0	7	0	0	21	#	7
MAR	15	2	9	4	#	7	0	0	23	#	7
APR	14	2	5	2	0	6	0	0	15	0	7
MAY	16	2	#	#	#	10	0	#	3	0	8
JUN	15	2	0	0	#	14	0	#	#	0	8
JUL	14	2	0	0	#	13	0	#	0	0	8
AUG	15	2	0	0	#	12	0	#	0	0	8
SEP	17	4	#	0	0	11	0	0	1	0	7
OCT	17	4	1	#	0	7	0	0	10	0	7
NOV	17	4	3	1	0	6	0	0	17	0	7
DEC	16	3	7	3	#	7	0	0	23	#	7
ANN	187	32	40	16	#	108	0	#	136	#	7
EYR	24	24	24	24	24	24	24	24	24	24	24

REMARKS:

SMOS (NAVY) POR: Hrly and Daily Obs: Jan 46 - Dec 69

Table 15-6 (Concluded)

Local Kodiak Climatological Data Providing 10- and 20-Yr Averages

NOTE: *DATA NOT AVAILABLE. #LESS THAN 0.5 DAY, 0.5 OR 0.5 INCH, OR 0.5 PERCENT (%) AS APPLICABLE.

FLYING WEATHER (% FREQ)	HOURS (LST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	EYR
	00-02	36	38	34	36	48	44	38	34	34	31	34	34	37	
CIG	03-05	38	39	36	37	49	46	41	35	35	31	35	35	38	
less than	06-08	37	40	39	38	48	47	40	34	38	31	37	38	39	
3000 feet	09-11	38	42	37	38	48	47	39	34	37	30	36	38	39	
and/or	12-14	38	42	37	37	47	43	37	34	37	30	37	38	38	
VSBY	15-17	40	43	37	38	45	42	38	34	38	33	40	39	39	
less than	18-20	37	42	38	38	46	42	39	32	37	33	36	36	38	
3 miles	21-23	36	40	35	37	47	44	38	33	35	31	35	36	37	
	ALL HOURS	38	41	37	37	47	44	39	34	36	31	36	37	38	24
	00-02	22	24	21	19	26	29	24	22	20	14	16	18	21	
CIG	03-05	24	24	20	21	27	30	26	22	20	13	16	18	22	
less than	06-08	23	25	22	21	27	30	26	21	20	13	16	20	22	
1500 feet	09-11	22	26	21	20	25	27	22	19	19	12	17	20	21	
and/or	12-14	22	27	21	19	24	24	20	18	17	11	16	19	20	
VSBY	15-17	25	27	21	20	24	24	21	17	18	12	18	21	21	
less than	18-20	23	26	22	21	25	27	22	17	19	13	16	20	21	
3 miles	21-23	22	25	21	20	27	28	24	19	20	14	16	19	21	
	ALL HOURS	23	25	21	20	26	27	23	19	19	13	16	19	21	24
	00-02	16	16	13	14	17	23	20	17	15	8	10	11	15	
CIG	03-05	17	17	15	13	19	24	21	18	15	7	10	11	16	
less than	06-08	16	18	15	13	17	24	21	17	16	8	10	12	16	
1000 feet	09-11	16	19	15	12	16	21	17	15	14	7	10	13	15	
and/or	12-14	15	20	15	11	16	19	14	14	12	7	9	12	14	
VSBY	15-17	17	18	14	13	15	20	15	13	14	7	10	13	14	
less than	18-20	15	19	16	13	16	22	17	15	15	8	9	12	15	
2 miles	21-23	15	17	16	12	16	22	19	15	15	8	10	12	15	
	ALL HOURS	16	18	15	13	17	22	18	15	14	8	10	12	15	24
	00-02	2	2	2	1	1	4	3	3	3	1	1	1	2	
CIG	03-05	2	3	2	1	2	5	5	4	3	#	1	1	2	
less than	06-08	2	2	2	1	2	4	4	3	3	1	1	1	2	
200 feet	09-11	3	3	2	#	2	3	2	3	2	#	1	2	2	
and/or	12-14	3	3	2	1	1	3	1	1	3	#	1	1	2	
VSBY	15-17	3	4	2	1	2	2	2	2	2	#	1	2	2	
less than	18-20	3	3	2	1	2	3	3	2	2	1	1	1	2	
1/2 mile	21-23	2	2	2	1	2	4	4	3	1	1	1	1	2	
	ALL HOURS	3	3	2	1	2	4	3	3	2	1	1	1	2	24

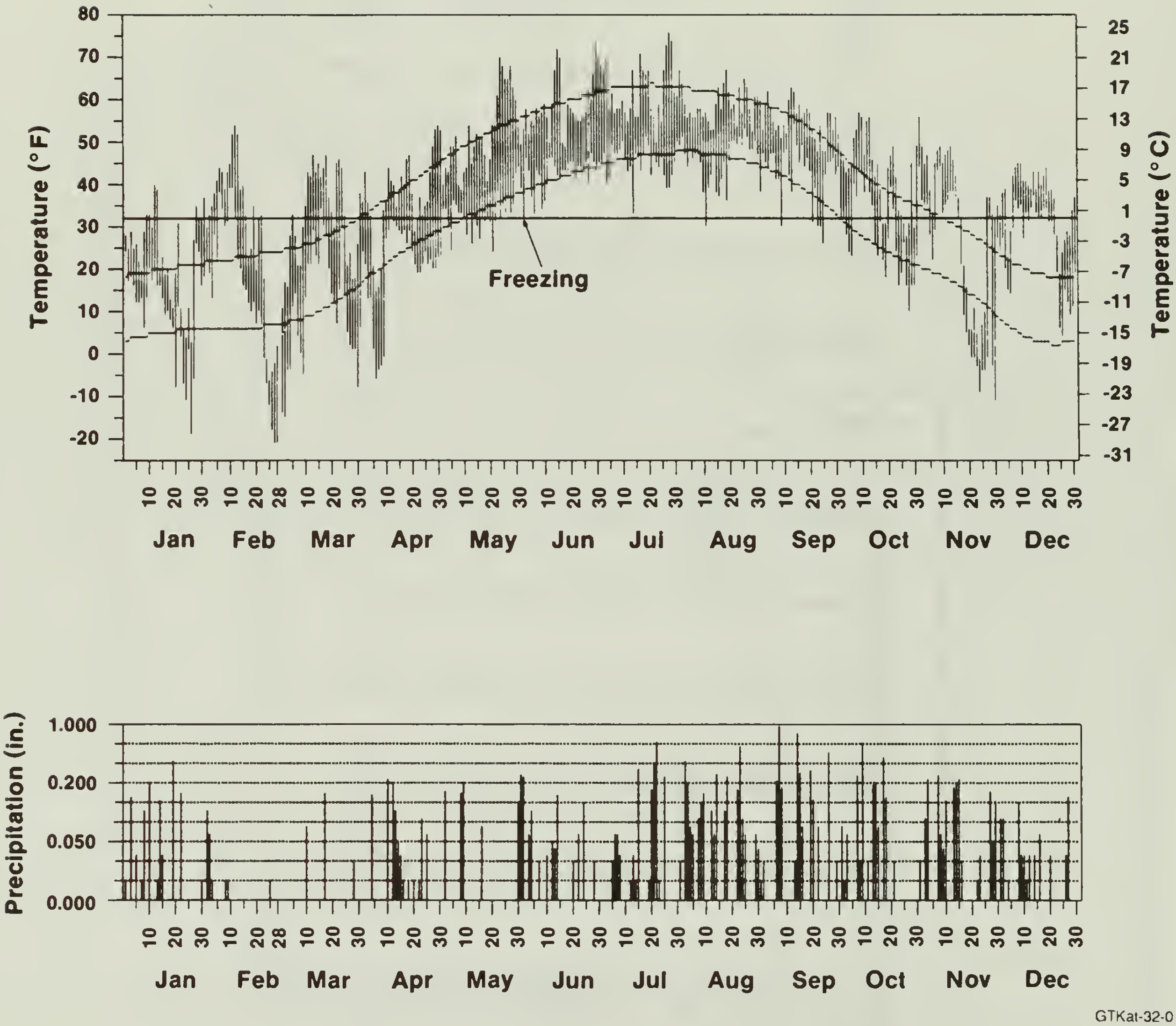


Figure 15-7. Climatological Data for King Salmon in 1986

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APPENDIX A

AIR QUALITY CONSIDERATIONS

APPENDIX A

AIR QUALITY CONSIDERATIONS

A.1. Burn Plan

It is planned to burn paper, paper products, and wood. Permission to burn these materials for the duration of the operation at the dome site is requested. A small incinerator will be employed that will provide adequate draft and will help ensure that the material is burned efficiently and safely. The amounts to be burned should not exceed 200 lb per day, usually less. These amounts are well below state limits for incinerators of 1,000 to 2,000 lb per hr.

The following procedures will be employed:

- noncombustibles will be separated from those materials to be burned;
- sufficient draft will be acquired for maximum combustion efficiency, and combustibles will not be allowed to smoulder;
- pesticides, halogenated organic compounds, and polyurethane will not be burned. No hazardous materials will be burned.
- Garbage or petroleum-based materials will not be burned if they emit odor or black smoke.
- Burning will be conducted away from camp buildings and petroleum storage areas.

Burning will occur at the darkest hours to minimize visibility impact for any tourists. There are no population centers nearby. Weather advisories will be obtained through the camp's support helicopters and the radio nets used by the operation. Burns will not be conducted when weather conditions pose a potential hazard. The NPS will be notified when burning is contemplated. Burning will occur approximately four times a week. Personnel will undergo training in the used of the incinerator.

A.2. Power Output of Machines

The power output of machines and elements of this operation are shown in Table A-1.

Table A-1

Estimated Power Output of Machines and Other Elements of the Operation (in horsepower [HP])

Item	Power Type*	Quantity	Unit Power	Total**	Average Utilization
Dome Drill Site and Camp					
Drill	D	1	250 HP	250 HP	.8
Camp, Elec. per/statewide +	G	1	35 KW	47 HP	.5
Camp, Tent HTRS	F.O.	14	50 K BTU/HR	275 HP	.5
Camp, Rec + Kit + Bath + Office	F.O.	4	75 K BTU/HR	118 HP	.5
Camp, Kit/Stove	P	2	10 K BTU/HR	8 HP	.25
Camp, Bath + Kit/ Hot Water	P	3	50 K BTU/HR	60 HP	.25
Camp Pumps	G	-	EST	3 HP	.5
Dewatering Equip. (Centrifuge + Feed + Misc.)	G	1	80 HP	80 HP	.5
Lights, Not Camp	G	15	0.250 KW	5 HP	.5
Rig, Misc. Elec. Power	G		EST	5 HP	.5
Fluids Shed HTR	F.O.	1	50 K BTU	20 HP	.5
Drill + Mech. Shed	F.O.	2	50 K BTU	40 HP	.25
Mod. System	G		EST	20 HP	.5
Mud Pump	D	1	30 HP	30 HP	.5
Water Tank HTRS	P	7	300 K BTU/HR	825 HP	.2
NAVI Drill	D		EST	100 HP	.05
Cement Equip.	D		EST	250 HP	.05
Logging Skid	G		EST	25 HP	.1

*D--Diesel generated powered
G--generator powered
F.O.--fuel oil
P--propane.
**Power Output Converted to HP.

Table A-1

Estimated Power Output of Machines and Other Elements of the Operation (Concluded)

Item	Power Type*	Quantity	Unit Power	Total**	Average Utilization
Compressor, 1400 CFM/200 psi	D		EST	250 HP	.1
Mechanics Shed	G		EST	7 HP	.5
Kill Pump	D		EST	100 HP	.01
Logging Skid, HTR	F.O.		EST	20 HP	.1
<u>Ash-Flow Site</u>					
Drill	D	1	~125 HP	125 HP	.8
Survival Tent HTR	F.O.	1	50 K BTU/HR	20 HP	.25
Logging Skid, HTR	F.O.	1	50 K BTU/HR	20 HP	.1
Fluid Storage, HTR	F.O.	1	50 K BTU/HR	20 HP	.5
Lights	G	7	0.250 KW	3 HP	.5
Dewatering Equip.	G	1	80 HP	80 HP	.5
Mud System	G	1	EST	20 HP	.5
Mud Pump	D	1	30 HP	30 HP	.5
Water Tank Heater	P	1	300 K BTU/HR	120 HP	.2
Waterline Pump	D	1	30 HP	30 HP	.8
Kill Pump	D	-	EST	50 HP	.01
Cement Equip.	D	-	EST	150 HP	.05
Logging Skid, Elec.	G	1	EST	10 HP	.1
Compressor 700/250	D	-	EST	175 HP	.1
<u>Waterline</u>					
Pump	D	4	30 HP	120 HP	.8
Waterline HTR	P	5	300 K BTU/HR	590 HP	.1

*D--diesel generated powered
G--generator powered
F.O.--fuel oil
P--propane
**Power Output Converted to HP

APPENDIX B

GENERIC OPERATING PROCEDURES AND SAFETY PHILOSOPHY AT GEOTECHNICAL SITES

GENERAL SAFETY OPERATING PROCEDURE FOR ORGANIZATION 6100 GEO ENERGY TECHNICAL FIELD WORK

BACKGROUND

The Geoscience and Technology Center (6100) at Sandia National Laboratories is involved in remote-site drilling and/or experimental operations. In 1987 the Geothermal Research Department of the Center recognized the need for a general set of Safe Operating Procedures (SOPs) that could be applied to a variety of projects. A general set was developed that could then be supplemented with site/project-specific SOPs as addenda. Other documents such as emergency action summaries, maps for evacuation, and National Park and State regulations can also become addenda.

Operations at geotechnical sites may involve the following:

- powerful machinery that rotate and lift heavy hardware overhead,
- considerable electrical power,
- steam/hot fluids vented from the geologic formation,
- hot surfaces on pipe, downhole tools, and other hardware periodically brought to the surface,
- lethal concentrations of formation gases,
- simultaneous onsite operations by personnel from several companies/national labs/universities,
- shared equipment and various well logging techniques that may require high voltages and explosives, and
- 24-hour per day operation (usually two 12-hour shifts) for several months.

The potential for accidents and serious injury is present. General SOPs have been prepared by the Geothermal Research Division for the following: General Field Work, H_2S Monitoring and Emergencies, Shared Operations, and Access Control.

Preparation of an SOP package forces the project personnel to consider the potential hazards, the consequences of unsafe practices, emergency procedure, and the development of safety consciousness that can reduce the risk of injury.

BASIC PHILOSOPHY OF SAFETY

Several basic tenets drive the safety philosophy:

- Safety is a basic ingredient of the project, not just a corporate requirement.

- Remote locations are special cases that require a high level of safety and emergency preparedness awareness and planning.

- Safety professionals should be involved in the initial planning and become contributing members of the project team.

- Project personnel will embrace the safety plans if the plans are reasonable and flexible and if safety is promoted as a logical concern for the common welfare.

- Perceptions of safety issues by project personnel may vary due to personalities, technical disciplines, and experience bases. Perceptions are real and must be dealt with if they are counter to good safety practice.

- A composite project group [Sandia National Laboratories (SNL), other labs, contractors, universities, government personnel, etc.] at a remote site requires close coordination on safety issues. One institution must be designated as the lead on safety, and a clear line of authority must be established.

- Adequate training of site personnel is absolutely essential and helps to develop proper safety attitudes.

- Real-time field decisions on safety issues usually must be made by the field safety coordinator, and the authority to make those decisions must be delegated by management.

- Management and oversight agencies must be willing to have an operation staffed adequately so that long shifts and fatigue do not become causative factors in accidents. There must be sufficient site personnel to deal with any drilling contingency.

This basic philosophy is incorporated into the project from the planning stage through the project conclusion. Typical project phases included in safety considerations are the following:

- contractor negotiations,

- personnel selection and assignment,

- start-up (a particularly critical time as various groups of people begin working together under operational conditions),

- continuing operation (familiarity and routine may lead to lapses), and

- demobilization (critical time, since people are anxious to tear down and leave the site to return home).

SAFETY PLANNING, IMPLEMENTATION, AND MONITORING

Planning

Planning for safe operation of a geotechnical field operation should include the costs of personnel time (project personnel and in-house service organizations such as safety, environmental health and medical groups and other support staff) needed to deal with safety issues as well as the obvious budget considerations for safety equipment and contractor support for specialized services.

Management must be willing to delegate a level of authority to the field safety coordinator that is in direct proportion to the responsibility placed on the coordinator. Recognizing that remote operations are unique, management cannot expect to always be consulted in every decision; therefore, seasoned personnel should be chosen for critical field positions and be given latitude to address unforeseen safety issues within the framework of the project safety philosophy.

Working interfaces regarding safety must be established. It is essential that representatives from all concerned organizations be involved in early project meetings and that safety is one of the primary concerns discussed. Clarification of responsibility and authority for site safety implementation is an important subject at this point.

Implementation

Administrative controls (procedures, signs, visitor logs, etc.) are employed at the site as soon as there is appreciable activity. The need for special protective equipment should be anticipated ahead of the actual need and should be onsite and in working order. Personal protective equipment (safety glasses, safety shoes, hard hats, etc.) shall be worn as required.

Attitudes regarding safety can be shaped by project leaders and safety coordinators who must model the behavior expected from other site personnel. Appeals to common sense, basic good judgment, and teamwork in training sessions add to the shaping of attitudes. Using competent, experienced instructors in first aid, cardiopulmonary resuscitation (CPR), and self-contained breathing apparatus (SCBA) training sessions reinforces that safety will be treated seriously on the project. Anyone with operational responsibilities at the site is required to read the SOPs and verify by signature that they understand and will abide by the safety requirements.

Physical barriers may be needed to remind site personnel of certain hazards as well as to prevent visitors from entering high risk areas. Causal visitors will always be escorted by site personnel if access to an active working area is required. For example, the drill rig foreman always has veto power for requests for access to the rig floor. Concentric zones defining controlled areas with higher risk near the center may be established with either soft or hard barriers, as appropriate.

The site safety coordinator must have the recognized authority to discipline anyone on the site for safety lapses. The safety coordinator

should make a reasonable effort to resolve the problem before taking action against the offender. This attempt at resolution may involve the foreman of the drilling crew, a senior scientist, the project leader, or any other authority figure onsite.

Monitoring

Periodic monitoring to see if safety rules are being followed is essential. This is done by the safety coordinator on a daily basis in the course of the project as well as on a periodic basis by other project personnel. Occasional random checks by safety, environmental health, fire prevention, and other professionals are valuable because an outsider's view is not colored by familiarity. As the project progresses, additional safety issues may need attention, and new procedures can be considered addenda to the original SOPs.

EMERGENCY PREPAREDNESS

Safety planning, training, implementation, and monitoring can reduce the probability of an accident or injury occurring; however, the probability can never be reduced to zero. Therefore, an emergency preparedness plan must be developed and employed at the site. Site personnel must be informed and trained in execution of the plan, and offsite responders must be aware of the planning for emergencies.

Offsite Emergency Resources

Geotechnical operations may be located in remote areas where emergency services are available, but the response time to the site can be lengthy due to several factors. Most emergency medical service (EMS) systems in small towns are staffed by dedicated volunteers that are alerted by the EMS system and then respond to the fire station to get the necessary equipment before they start to the scene. Some areas do have volunteers equipped to respond from their homes/job locations and at least provide first-responder evaluation and stabilization of victims. Access to a remote site can be over rough roads or may require helicopter transport, and this can impact response time.

Assessing the local resources and response times in the event of an emergency is one of the first considerations in developing an emergency preparedness plan. This can be done by visiting the local fire station, police department, or medical clinic/hospital. Meeting and talking with these people and establishing a working relationship and trust (remember, the project and its personnel are outsiders) is important to efficient activation of these people, if the need arises. It is extremely important to brief them on the location of the site, potential injuries, site-specific hazards, etc.

Onsite Emergency Resources

The key to the proper onsite response to emergencies is well-trained site personnel. The proper equipment must also be available for use. A well-equipped trauma kit, a backboard, and supplemental oxygen are basics. SCBAs for rescue and shutting down the drill rig in the event of a toxic gas release are also on hand. Initial training in first aid, CPR, and the use of

all emergency equipment is given to all site personnel with operational responsibilities prior to start-up. Periodic refresher classes and training of new people coming onsite to work is also scheduled.

> **Comment: Several comments have been made by site personnel indicating that the training was appreciated, and that the quality of the training and the competence of the instructors was excellent. Some workers would take the initiative to practice and refresh their memory on certain emergency procedures at slack times in the operations.**

A communication center is established at the site and succinct procedures are posted at the center for emergency use. Telephone lines are not always available, or if available, they are not reliable. Therefore, radios on several nets are provided. These radio nets may be established with the NPS, private landowners, a local emergency organization, or a special net established by the site personnel with communication to accommodations where the off-shift crew is headquartered.

Evacuation plans are required for sites having the potential for toxic gas release. Evacuation plans vary depending on the wind direction, day or night situations, etc. A regrouping area is designated for each scenario so that a head count may be taken.

Periodic tests of emergency equipment and gas sensing systems are necessary. Every effort is made to resolve and eliminate false alarm problems so that the entire site crew has confidence in the systems. Also, emergency drills are held at slack times to check the response of the site crew.

Post-Emergency Critique

This critique of any emergency action taken serves to improve on the emergency plan as well as to give site personnel an opportunity to have additional input into the plan. Hindsight tends to be 100-percent correct whereas foresight is seldom 100 percent. The emergency plan can be improved by a review and frank discussion following the emergency.

GENERAL SAFETY OPERATING PROCEDURE
FOR DEPARTMENT 6111 GEOTECHNICAL FIELD WORK

APPLICATION

The general philosophy and requirements of this SOP are intended to apply to a broad range of applications. Department 6111 is involved in various field activities related to geotechnical research. Typical activities include, but are not limited to, geophysical surveys prior to a drilling operation, onsite instrumentation and control of surface and down-hole devices, developing drilling strategies, overall drill site coordination, interfacing with scientists from government and university groups, and follow-up well logging with unique, state-of-the-art instruments.

PHILOSOPHY

This SOP is structured to be general in nature and to point out a number of situations where potential hazards could arise in field work involving geotechnical experiments. Site-specific and/or operation-specific situations requiring greater detail on potential hazards will be developed as separate addendums and appended to this general SOP. The signatures of all users and the appropriate management approvals should appear on the general SOP and on all appended documents to signify awareness of agreement with, and commitment to comply with, the content. The SOP should cause the users to think about the potential hazards and then to operate in such a way as to minimize the risk without causing unnecessary frustration in conforming to the SOP. An SOP cannot prevent injury to the users. Only the users themselves can minimize the risk of injury by conscientious attention to the situation and awareness of the hazards.

Management Expectation and Delegated Authority - Management expects the users to demonstrate a certain level of personal responsibility in conforming to the SOP; however, a certain measure of delegated authority must accompany the expectation for responsibility. The discretion necessary in using this delegated authority must be agreed to both by management and the personnel involved. Examples of the use of this authority could be the following: shutting down an operation and excluding all personnel until unanticipated results are understood; observation of unsafe practices by a coworker and immediate notification of management if the problem cannot be diplomatically resolved; and asserting oneself in the face of pressure to complete a test on schedule by taking certain unsafe shortcuts.

POTENTIAL HAZARDS

Field work contains a variety of potentially hazardous situations. Examples are the following: large powerful machinery that rotate and lift heavy hardware; considerable electrical power to run the machinery; toxic gases, steam, and hot fluids vented from the geologic formation by the drilling operation; hot surfaces; simultaneous onsite operations by personnel

from several companies; shared equipment; well logging operations involving high voltages; and the use of explosives.

All onsite personnel must be made aware of the potential hazards and the proper responses to any emergencies that might occur in spite of the physical and administrative controls imposed by the SOP.

Non-GRDO personnel from other laboratories, universities, and institutions frequently spend considerable time onsite. These individuals should be required to read and signify by signature that they understand and will abide by the requirements of the SOPs.

Management must be sufficiently aware of the field workload to adequately staff an operation so that long shifts and fatigue do not become causative factors in accidents. Proper responses to emergency situations can be impacted by fatigue.

RESPONSIBILITIES AND PERSONNEL ASSIGNMENTS

Clear-cut lines of responsibility must be established prior to starting a field operation. If teams are established with multidisciplinary backgrounds and different levels of field experience, it is particularly important to assure that each team member understands his responsibility and the limits of that responsibility. Selection of a particular team should be based on the good management practice of utilizing talent, experience, interest, and attitude. Briefings should be conducted, as appropriate, by the team leader to advise all personnel of significant changes in procedure, particular problems that have arisen, anticipated problems for their shift, and any other information that impacts safe operation. All personnel should be encouraged to ask questions about things that they perceive to be safety problems. Perceptions are real, although the problems may not be.

Operations involving personnel from several institutions and agencies need particular attention to assure that appropriate safety issues have been addressed. Ideally, joint agreements regarding safety planning should be made. Agreements may be simple lists of concerns or more complicated definitions of responsibilities. A document of this sort should be appended to this general SOP.

EXCLUSION AREAS

Exclusion areas shall be established, as appropriate, to exclude non-essential personnel. Breaching of the barriers will be considered a violation of the safety guidelines. Proper respect for the barriers reinforces the seriousness with which GRDO treats safety and sets an example for the non-GRDO workers at the site. The division of turf and responsibility at the remote site occupied by various personnel is recognized as a delicate subject, but that division must be delineated as clearly as possible and must continue to be clarified as problems arise.

PERSONAL PROTECTIVE EQUIPMENT

Appropriate personal protective equipment will be used by the operating personnel. Hard hats, safety shoes, and eye protection are the most basic protective equipment. Spare equipment shall be available at the site for visitors requiring entry to areas requiring protection. Additional special protective equipment may be required by the site-specific safety plan.

EMERGENCY PREPAREDNESS

Providing a site-specific emergency preparedness plan is an essential part of this SOP. The emergency planning document should contain a discussion of the logic pertaining to an emergency response as well as details of specific issues. The emergency resources available in a region must be ascertained. An appropriate means of communication within the test site and external to the site should be available and tested periodically. If external radio or telephone communications are not available due to geographic features or remoteness of the test site, a reliable conveyance must be readily available for use in emergencies. A critical actions list must be posted in the control area and must be clearly identifiable. The emergency preparedness plan should be appended to this SOP.

Appropriate emergency equipment should be available at the test site with an industrial first-aid kit as a minimum. Also, personnel should be trained in the proper use of whatever equipment is deemed necessary.

Basic training in first-aid and CPR techniques shall be provided for all personnel regularly participating in field tests. Other companies and institutions participating in a field operation are responsible for assuring that their personnel are properly trained and equipped.

PROFESSIONAL CONDUCT

Professional conduct in keeping with the Sandia National Laboratories Code of Conduct is absolutely essential for Sandia National Laboratories personnel at all times while onsite and operating under the safety guidelines. Therefore, practical jokes or other activities that even remotely affect safety will not be tolerated. The professional integrity of Sandia National Laboratories, Albuquerque, as an organization can be undermined by inappropriate behavior.

CONTINUING AWARENESS OF HAZARDS

It may not be possible to identify all significant hazards before beginning a geotechnical field operation. Therefore, it is important that all operating personnel be continually alert to safety concerns that may develop. This general SOP may be appended at any time with additional information.

AUTHORIZED PERSONNEL

Signatures on the Site Signature List signify that the personnel authorized to work on the site have read and agree with the content of this SOP and all appropriate addendums and will abide by the requirements.

GENERAL GUIDELINE STANDARD OPERATING PROCEDURE FOR OPERATIONS SHARED BY SNLA/OTHER AGENCIES AT GEOTECHNICAL TEST SITES

GENERAL

Shared operations have the potential for miscommunication and unclear lines of responsibility and authority. The end result is an adversarial relationship between participating personnel, i.e., scientists, visitors, contract workers. The intent of this general SOP is to clarify some of the issues and to impose procedures to avoid some of the problems.

Each participating institution has its own method of operation based on the task to be performed. Also, the operating staff of each institution has certain talents, skills, and personal preferences in completing their task. It is the meshing of these policies and personal preferences that will develop and implement joint safety guidelines. A single overall site officer representing the Legal Operator of the site shall have the authority to make real-time decisions.

OBVIOUS HAZARDS

Obvious, significant hazards will be recognized by all personnel. It is likely that responses to potential emergencies caused by those hazards will be similar, but will differ somewhat based on different experience bases.

SUBTLE HAZARDS

These may be discovered by site personnel and pointed out to others. If everyone has respect for each other, a sense of appreciation will be developed for the personnel watching out for each other's welfare.

INTERMEDIATE HAZARDS

These are hazards and situations identified by one person or group but not fully accepted as hazards by others. Judgment on these issues may be colored by experience, emotion, financial penalties, personality conflicts, fatigue, and so on. These issues have the potential for severe conflicts between personnel. A method of resolving these potential conflicts must be agreed to prior to beginning operations. Exclusion area boundaries can help to define physical areas of responsibility. However, when actions within a boundary can affect personnel in other areas, some means of resolution must be available. As previously stated (and repeated for emphasis), a single overall site officer representing the Legal Operator of the site shall have the authority to make real-time decisions.

LEGALITY

This document is only to be used as a guideline for development of working documents and agreements that may be needed between the GRDO and others sharing a geotechnical field site.

AUTHORIZED PERSONNEL

Signatures on the Site Signature List signify that the personnel authorized to work onsite have read and agree with the content of this SOP and all appropriate addendums and will abide by the requirements.

GENERAL SAFETY OPERATING PROCEDURE FOR GEOTECHNICAL FIELD SITES WITH POTENTIAL HYDROGEN SULFIDE EMISSIONS

GENERAL

Geotechnical sites often have hydrogen sulfide (H_2S) gas present in the geologic formation. Sometimes this gas can be detected at the surface (a rotten-egg smell) even before exploration or drilling begins. This gas can be fatal when inhaled in relatively low concentrations. Immediate medical treatment is necessary if a person is overcome. Emergency breathing apparatus should be available onsite for use in escaping a large, unexpected release or for entry into an area where emergency work must be performed.

SENSING AND ALARM SYSTEM

An appropriate sensing and alarm system must be available prior to any significant amount of field work. The Sandia National Laboratories Albuquerque Industrial Hygiene/Toxicology, Department 7211 or 7212, will establish the need, provide proper equipment/training procedures, and monitor compliance with this SOP. Initial and periodic testing/calibration of the sensing system is required. The system may consist of both fixed-position and portable sensors, or in simple operations, could encompass only portable equipment. Details of the sensing system and persons to contact in case of malfunction shall be included in the site-specific SOP and posted in the control area.

The sensing system shall have two alarm levels (low and high). The ppm concentrations for these alarm levels shall be dictated by Department 7211 or 7212. Each level shall have a unique, audible, and visual alarm that can be heard and seen from prominent locations at the site. A wind sock shall be installed in the most favorable location at the site to indicate surface wind direction.

RESPONSE TO ALARMS

Each time that the alarm system triggers, the onsite personnel must assume that the alarm is valid and must react properly. The proper response may vary depending on the situation (e.g., alarm level, wind direction, and location of personnel). It is assumed that the control area location is sufficiently remote from the probable gas release area so that control area personnel can immediately determine which sensor is triggering. Operating personnel evacuation from the area indicating a release is always appropriate, and clearing other areas may also be necessary. Total test site evacuation is an extreme measure but might be necessary.

Operating personnel may need to re-enter an area that has an unsafe concentration of H_2S to secure equipment, which if left unattended, could cause additional hazards. If reentry is necessary, appropriate self-contained breathing apparatus will be required.

This apparatus should only be used by those trained in its use. Therefore, all people who will work at the drill sites will be trained in its use. A buddy system shall be used by anyone using the apparatus. Strict adherence to the low supply warning devices on the apparatus is required and is reinforced by the buddy system.

If there are victims that have been overcome, appropriate first aid can be applied. Simultaneously, activation of the local emergency services network must be initiated to acquire more advanced medical support.

EQUIPMENT MALFUNCTIONS

False alarms from malfunctioning equipment are detrimental to safe operation. The alarm system must be trusted by the users. Any malfunction must be immediately corrected so that overall system confidence is restored.

Self-contained breathing apparatus should be checked at least weekly to verify readiness for use. Spare apparatus and replacement air tanks should be stored near the control area and protected from the elements.

BRIEFING OF NEW PERSONNEL

All personnel entering the test site and having reason to work in an area that could develop hazardous levels of H_2S should be briefed by the site supervisor on the current situation, should be required to read the SOPs, and should signify by signature their intent to comply. Site personnel should also be fully aware of the requirements of this SOP and know how to activate the local emergency services network.

AUTHORIZED PERSONNEL

Signatures on the Site Signature List signify that the personnel authorized to work onsite have read and agree with the content of this SOP and all appropriate addendums and will abide by the requirements.

APPENDIX C

CONSIDERATIONS OF WATER QUALITY AND RCRA DATA FOR THE WATER AND ROCK SAMPLES FROM THE VALLEY OF TEN THOUSAND SMOKES

APPENDIX C

CONSIDERATIONS OF WATER QUALITY AND RCRA DATA FOR THE WATER AND ROCK SAMPLES FROM THE VALLEY OF TEN THOUSAND SMOKES

C-1 Possible Influence of Drilling on the Salt Content of Water From the Valley of Ten Thousand Smokes, Katmai National Park

The Cl and K content in the waters of the Valley of Ten Thousand Smokes would be affected minimally by drilling with 3% KCl in the drilling fluid, using an average of 4,000 gal per day during drilling. Drilling would have minimum impact because these waters are influenced naturally by active hydrothermal processes related to volcanism. This is because of the influx of thermal springs of hydrothermal origin having a fairly high salt content and because of leaching and alteration of pumice and ash from the 1912 eruption. More Cl and K ions dissolve naturally into the streams and rivers of the Valley of Ten Thousand Smokes as a result of these thermal springs and the leaching processes than could be injected into these waters by putting all of the assumed drilling fluid or well production returns directly into the streams. (This is a hypothetical demonstration of the impact; no drilling products whatsoever will be deposited in streams or rivers.)

The River Lethe and Knife Creek water systems dominate the Valley of Ten Thousand Smokes and are located mostly within the ash-flow sheet (Figure A-1). Possible hydrological paths from the drill sites would lead to either or both of these water systems. These two water systems join to form the Ukak River. Windy Creek, which joins this water system, is mostly outside of the ash-flow sheet and shows far less influence by these hydrothermal alteration processes.

A baseline of water chemistry data exists for the waters of the valley influenced by hydrothermal processes (Knife Creek, the River Lethe, midvalley thermal springs, and other thermal springs), and for Windy Creek, which will be considered a baseline for a stream unaffected by the hydrothermal alteration processes. Data from other streams above the ash-flow sheet are also available. The calculations of Cl flux and other naturally occurring ions are based on the stream flow and Cl concentration measurements of T. Keith and S. Ingebritsen (1991) and the earlier extensive ion concentration measurement of T. Keith, J. Thompson, R. Hutchinson, and L. White in the *Journal of Volcanology and Geothermal Research* (in preparation).

The ion flux data in Table A-1 are derived directly or indirectly from the data of Keith and Ingebritsen and Keith et al. and are based upon water sampling and stream flow measurements in the lower parts of the River Lethe (Figure C-1, Location 5), Knife Creek (locations 3 and 4), midvalley thermal springs draining into Knife Creek (location T1), and Windy Creek (Locations 6 and 7). Furthermore, Keith and Ingebritsen clearly imply that a considerable part of ion and heat flux from both Knife Creek and the River Lethe emanates from <u>what must be as yet undetected saline thermal springs</u>.

In Table C-1 the Cl and K flux from these water systems are compared with the flux that would be produced using the above drilling assumptions.

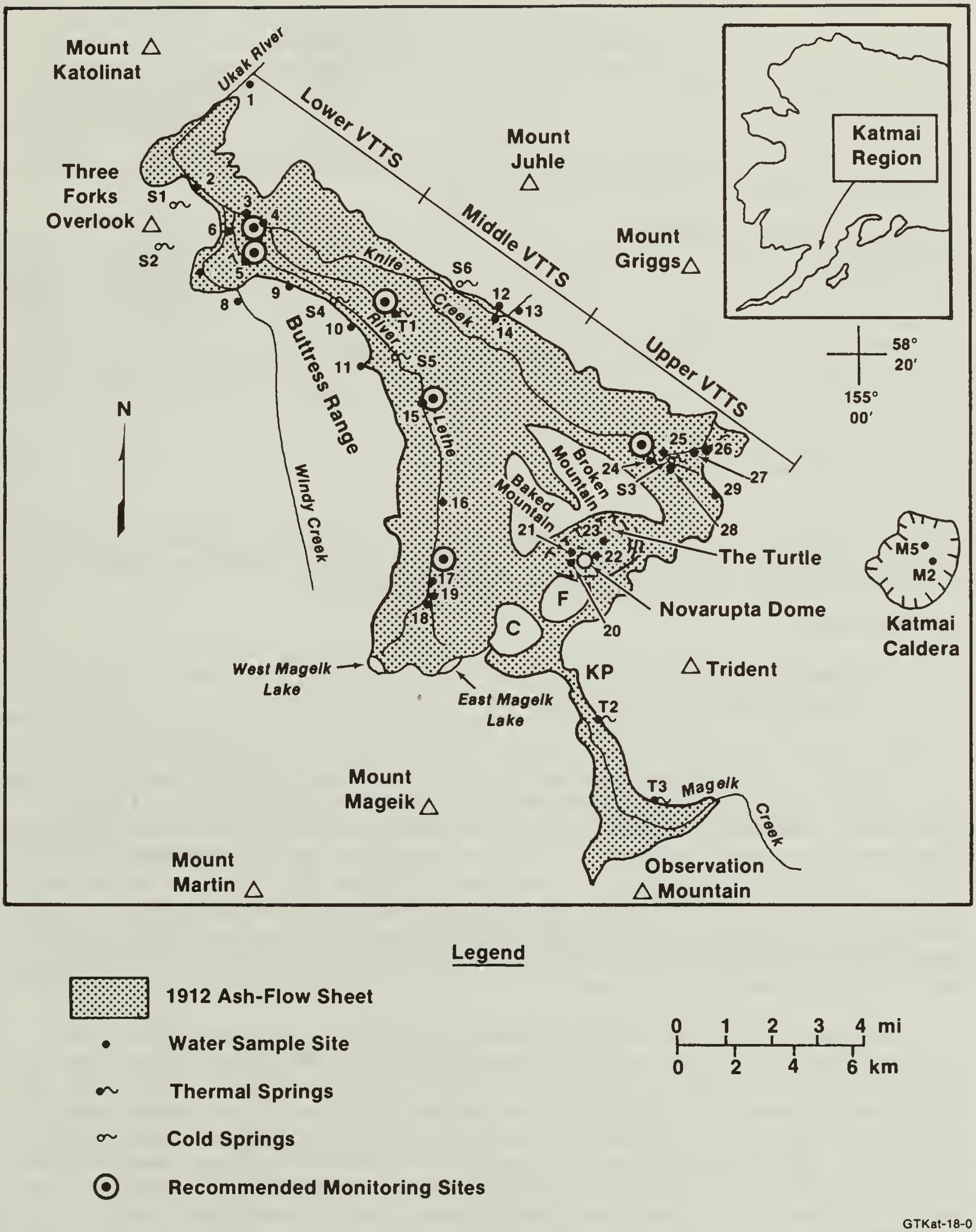

Figure C-1. Earlier Water-Sampling Locations and Proposed Monitoring Locations

Table C-1

Comparison of Flux of Cl and K
Ions for Conditions Noted Below

Water Source	Ion Flux (kg/day)	
	Cl	K
Stream influenced by alteration processes		
Midvalley thermal springs	4,000	205
Lower River Lethe	11,000	1,100
Lower Knife Creek	46,000	2,800
Ukak River	61,000	3,100
Stream with little influence by alteration processes:		
Windy Creek	710	160
A "Typical" drilling fluid		
3% KCl, 4000 gal per day	140	160

*The stream flow and chemistry measurements are based on works of T. Keith, J. M. Thompson, S. Ingebritsen, L. D. White (all of USGS, Menlo Park) and R. A. Hutchinson (NPS, Yellowstone National Park)

OTHER COMMENT

1. Naturally occurring ion fluxes of the HCO_3, SO_4, CA, Na, SiO_2 are much closer to that of the Cl than K.

Table C-1 shows that the natural Cl flux is much larger, and the natural flow of K is also larger than the K produced from the proposed drilling operation. These estimates were made assuming that all water from drilling or fluid sampling would go either into Knife Creek or the River Lethe. In reality, the Katmai proposal for returned drilling fluids is to allow the treated drilling fluid to leach into the ground at the Novarupta Dome drill site <u>over a mile from either Knife Creek or the River Lethe, which are the nearest water systems</u>. Drilling fluid can go directly into the formation at depth through lost circulation.

Estimates from the data referenced above also show that alteration processes result in high natural fluxes of Ca, Na, HCO_3, and SO_4 in the midvalley thermal springs, lower Knife Creek, and the lower River Lethe and are close to that of the Cl ion. The natural Mg flux in the above water systems influenced by volcanism is smaller, but three to four times that of the K ion. The flux of Fe and SiO_2 are also elevated and are comparable to that of the Cl ion. Alteration also elevates the midvalley thermal springs, the lower River Lethe, and lower Knife Creek. All these fluxes are considerably elevated relative to the baseline data from Windy Creek, which traverses relatively little ash flow and does not appear influenced by saline thermal springs.

Therefore, Table C-1 shows that any possible presence of the KCl drilling fluid additive in valley waters should be masked by these manifestations of volcanism, at least downstream along the noted sampling locations and beyond. This masking argument can be shown to apply to ions contained in certain other common drilling fluid additives, soda ash, and sodium bicarbonate when used in normal drilling fluid concentrations of a few percent or less. These arguments would also hold for the less likely use of lime, caustic soda, or gypsum as drilling fluid additives.

A fairly large sediment content exists in both the River Lethe and Knife Creek, resulting from erosion of volcanic material from the 1912 eruption. While yet unquantified, it is anticipated that the high solid content in these water systems should mask any possible detection of drilling solids if they happen to reach the waters draining the valley. However, the environmental impact of <u>all</u> drilling fluid additives to be used in Katmai drilling will be considered, although the total amounts of these additives are relatively small or minor (to that of a standard oilfield operation).

* *

C-2 <u>TCLP Analysis of Volcanic Samples from Valley of Ten Thousand Smokes</u>

Tables C-2 and C-3 provide data from the Toxicity Characteristic Leaching Procedure (TCLP) analysis of volcanic samples from the Valley of Ten Thousand Smokes.

C-3 <u>Analyses of the Water Samples from the Valley of Ten Thousand Smokes</u>

Tables C-4 and C-5 provide data from analyses of water samples from the Valley of Ten Thousand Smokes under the EPA Clean Water Act protocol.

Table C-2

TCLP Analyses of Dacitic Ash-Fall Samples from the Valley of Ten Thousand Smokes--Fumarole at the Ash-Flow Site*

RED**

Total Calculation of RCRA Element			Leachite Extracted		
Parameter	Result (mg/kg)	Reporting Limit (mg/kg)	Parameter	Result (mg/L)	Reporting Limit (mg/L)
Barium	72.8	1.0	Arsenic	ND	1.0
Cadmium	ND	0.50	Barium	0.64	0.10
Chromium	12.6	1.0	Cadmium	ND	0.050
Lead	1020	5.0	Chromium	ND	0.10
Mercury	ND	0.10	Lead	ND	0.50
Selenium	ND	2.0	Mercury	ND	0.0020
Silver	ND	1.0	Selenium	ND	0.050
			Silver	ND	0.10

PINKISH WHITE***

Total Calculation of RCRA Element			Leachite Extracted		
Parameter	Result (mg/kg)	Reporting Limit (mg/kg)	Parameter	Result (mg/L)	Reporting Limit (mg/L)
Barium	62.6	1.0	Arsenic	ND	1.0
Cadmium	ND	0.50	Barium	0.15	0.10
Chromium	6.8	1.0	Cadmium	ND	0.050
Lead	10.0	5.0	Chromium	ND	0.10
Mercury	ND	0.10	Lead	ND	0.50
Selenium	ND	2.0	Mercury	ND	0.0020
Silver	ND	1.0	Selenium	ND	0.050
			Silver	ND	0.10

*ND--not detected.

**(dark brick red encrusted fallout outboard of gray)--plagioclase, pyroxene (primary phenocrysts); fluorite and trace of AHF from fumarolic alteration, brick red crusts are hematite/goethite but do not show up on whole-rock XRD.

***(pinkish, hard outer edge of fumarole deposit)--plagioclase, pyroxene (primary phenocrysts) and small amount of kaolinite from acid fumarolic alteration, trace of fluorite.

Table C-2

TCLP Analyses of Dacitic Ash-Fall Samples from the Valley of Ten Thousand Smokes--Fumarole at the Ash-Flow Site* (Concluded)

GREY**

Total Calculation of RCRA Element			Leachite Extracted		
Parameter	Result (mg/kg)	Reporting Limit (mg/kg)	Parameter	Result (mg/L)	Reporting Limit (mg/L)
Barium	125	1.0	Arsenic	ND	1.0
Cadmium	1.1	0.50	Barium	0.24	0.10
Chromium	11.5	1.0	Cadmium	ND	0.050
Lead	76.0	5.0	Chromium	ND	0.10
Mercury	ND	0.10	Lead	ND	0.50
Selenium	ND	5.0	Mercury	ND	0.0020
Silver	ND	1.0	Selenium	ND	0.050
			Silver	ND	0.10

*ND--not detected.
**(gray encrusted material from center of fumarole)--plagioclase, pyroxene (both primary phenocryst phases). Hand magnet shows that the gray crust contains abundant fine magnetite but whole-rock XRD does not pick it up.

Table C-3

TCLP Analysis of Volcanic Samples
From the Valley of Ten Thousand Smokes*

Total Concentration of RCRA Element	ppm	Leachate Extracted (ppm)	Reporting Limits (ppm)
1912 Dacite-Andesite-Rhyolite Ash-Flow Tuff With Andesite Lithics			
Arsenic	2.97	ND	1
Barium	862	ND	0.10
Cadmium	<5	ND	0.050
Cadmium (Reanalysis)	<5		
Chromium	46	ND	0.10
Chromium (Reanalysis)	44		
Lead	30	ND	0.50
Mercury	<0.05	ND	0.020
Mercury (Reanalysis)	<0.05		
Selenium	<0.1	ND	0.050
Silver	<1	ND	0.10
Silver (Reanalysis)	1		
1912 Dacite Pumice			
Arsenic	1.86	ND	1
Barium	958	ND	0.10
Barium (Reanalysis)	881		
Barium (Reanalysis)	844		
Cadmium	<5	ND	0.050
Chromium	29	ND	0.10
Lead	33	ND	0.50
Lead (Reanalysis)	53		
Mercury	<0.05	ND	0.020
Selenium	<0.1	ND	0.050
Silver	<1	ND	0.10

*ND--not detected.

Table C-3

TCLP Analysis of Volcanic Samples
From the Valley of Ten Thousand Smokes*
(Concluded)

Total Concentration of RCRA Element	ppm	Leachate Extracted (ppm)	Reporting Limits (ppm)
1912 Andesite and Dacite Pumice			
Arsenic	1.69	ND	1
Arsenic (Reanalysis)	1.48		
Barium	561	ND	0.10
Barium (Reanalysis)	561		
Cadmium	6	ND	0.050
Chromium	70	ND	0.10
Lead	35	ND	0.50
Mercury	<0.05	ND	0.020
Selenium	<0.1	ND	0.050
Selenium (Reanalysis)	<0.1		
Silver	1	ND	0.10

*ND--not detected.

Table C-4

Analysis of Water Samples From the Valley of Ten Thousand Smokes
Under EPA Protocol, June 1991*

Knife Creek at Three Forks			Midvalley Thermal Spring		
Parameter	Result (Mg/L)	Reporting Limit (Mg/L)	Parameter	Result (Mg/L)	Reporting Limit (Mg/L)
Arsenic	0.0054	0.0050	Arsenic	ND	0.0050
Barium	0.051	0.010	Barium	0.015	0.010
Cadmium	ND	0.0050	Cadmium	ND	0.0050
Chromium	ND	0.010	Chromium	ND	0.010
Copper	0.032	0.020	Copper	ND	0.020
Lead	ND	0.010	Lead	ND	0.010
Manganese	0.16	0.010	Manganese	ND	0.010
Mercury	ND	0.00020	Mercury	ND	0.00020
Nickel	ND	0.040	Nickel	ND	0.040
Selenium	ND	0.010	Selenium	ND	0.010
Silver	ND	0.010	Silver	ND	0.010
Zinc	0.033	0.020	Zinc	0.022	0.020

UKAK River			River Lethe (1 mi down from Ford)		
Parameter	Result (Mg/L)	Reporting Limit (Mg/L)	Parameter	Result (Mg/L)	Reporting Limit (Mg/L)
Arsenic	0.0059	0.0050	Arsenic	0.011	0.0050
Barium	0.048	0.010	Barium	0.11	0.010
Cadmium	ND	0.0050	Cadmium	ND	0.0050
Chromium	0.010	0.010	Chromium	ND	0.010
Copper	0.034	0.020	Copper	0.090	0.020
Lead	ND	0.010	Lead	ND	0.010
Manganese	0.12	0.010	Manganese	0.11	0.010
Mercury	ND	0.00020	Mercury	ND	0.00020
Nickel	ND	0.040	Nickel	ND	0.040
Selenium	ND	0.010	Selenium	ND	0.010
Silver	ND	0.010	Silver	ND	0.010
Zinc	0.037	0.020	Zinc	0.029	0.020

*ND--not detected.

Table C-4

Analysis of Water Samples From the Valley of Ten Thousand Smokes Under EPA Protocol, June 1991* (Concluded)

Midvalley Thermal Spring		
Parameter	Result (Mg/L)	Reporting Limit (Mg/L)
Arsenic	ND	0.0050
Barium	0.013	0.010
Cadmium	ND	0.0050
Chromium	ND	0.010
Copper	ND	0.020
Lead	ND	0.010
Manganese	ND	0.010
Mercury	ND	0.00020
Nickel	ND	0.040
Selenium	ND	0.010
Silver	ND	0.010
Zinc	ND	0.020

*ND--not detected.

Table C-5

Analysis of Water Samples From the Valley of Ten Thousand Smokes Under EPA Protocol, August 1991*

Fresh Water Spring			Thermal Spring 1/2 Way Down		
Parameter	Result (Mg/L)	Reporting Limit (Mg/L)	Parameter	Result (Mg/L)	Reporting Limit (Mg/L)
Antimony	ND	0.060	Antimony	ND	0.060
Arsenic	ND	0.0050	Arsenic	ND	0.0050
Barium	ND	0.010	Barium	0.015	0.010
Beryllium	ND	0.0020	Beryllium	ND	0.0020
Boron	ND	0.10	Boron	0.70	0.10
Cadmium	ND	0.0050	Cadmium	ND	0.0050
Calcium	19.2	0.20	Calcium	91.3	0.20
Cesium (133)	ND	0.0010	Cesium (133)	0.0063	0.0010
Chromium	ND	0.010	Chromium	ND	0.010
Copper	0.027	0.020	Copper	ND	0.020
Iron	0.26	0.10	Iron	0.20	0.10
Lead	ND	0.0050	Lead	ND	0.0050
Lithium	ND	0.050	Lithium	0.27	0.050
Magnesium	1.6	0.20	Magnesium	19.1	0.20
Manganese	ND	0.010	Manganese	ND	0.010
Mercury	ND	0.00020	Mercury	ND	0.00020
Nickel	ND	0.040	Nickel	ND	0.040
Potassium	ND	5.0	Potassium	ND	5.0
Rubidium (85)	0.0016	0.0010	Rubidium (85)	0.021	0.0010
Selenium	ND	0.0050	Selenium	ND	0.0050
Silica as SiO2	24.3	0.50	Silica as SiO_2	42.9	0.50
Silver	ND	0.010	Silver	ND	0.010
Sodium	6.9	5.0	Sodium	81.0	5.0
Strontium	ND	0.050	Strontium	0.21	0.050
Thorium (232)	0.0018	0.0010	Thorium (232)	0.012	0.0010
Zinc	ND	0.020	Zinc	ND	0.020

*ND--not detected.

Table C-5

Analysis of Water Samples From Valley of Ten Thousand Smokes Under EPA Protocol, August 1991* (Continued)

Snow Melt in Dome			Lake Mageik at Waterline Terminus		
Parameter	Result (Mg/L)	Reporting Limit (Mg/L)	Parameter	Result (Mg/L)	Reporting Limit (Mg/L)
Antimony	ND	0.060	Antimony	ND	0.060
Arsenic	ND	0.0050	Arsenic	ND	0.0050
Barium	ND	0.010	Barium	ND	0.010
Beryllium	ND	0.0020	Beryllium	ND	0.0020
Boron	ND	0.10	Boron	ND	0.10
Cadmium	ND	0.0050	Cadmium	ND	0.0050
Calcium	0.21	0.20	Calcium	4.0	0.20
Cesium (133)	ND	0.0010	Cesium (133)	ND	0.0010
Chromium	ND	0.010	Chromium	ND	0.010
Copper	ND	0.020	Copper	ND	0.020
Iron	ND	0.10	Iron	ND	0.10
Lead	ND	0.0050	Lead	ND	0.0050
Lithium	ND	0.050	Lithium	ND	0.050
Magnesium	ND	0.20	Magnesium	0.60	0.20
Manganese	ND	0.010	Manganese	0.019	0.010
Mercury	ND	0.00020	Mercury	ND	0.00020
Nickel	ND	0.040	Nickel	ND	0.040
Potassium	ND	5.0	Potassium	ND	5.0
Rubidium (85)	ND	0.0010	Rubidium (85)	ND	0.0010
Selenium	ND	0.0050	Selenium	ND	0.0050
Silica as SiO2	ND	0.50	Silica as SiO2	7.9	0.50
Silver	ND	0.010	Silver	ND	0.010
Sodium	ND	5.0	Sodium	ND	5.0
Strontium	ND	0.050	Strontium	ND	0.050
Thorium (232)	ND	0.0010	Thorium (232)	ND	0.0010
Zinc	ND	0.020	Zinc	ND	0.020

*ND--not detected.

Table C-5

Analysis of Water Samples From the Valley of Ten Thousand Smokes
Under EPA Protocol, August 1991* (Continued)

Snow Melt in Dome			Lake Mageik at Waterline Terminus		
Parameter	Result (Mg/L)	Reporting Limit (Mg/L)	Parameter	Result (Mg/L)	Reporting Limit (Mg/L)
Alkalinity, Total as CaCo3 at pH 4.5	ND	5.0	Alkalinity, Total as CaCO3 at pH 4.5	ND	5.0
Alkalinity, Bicarb. as CaCO3 at pH 4.5	ND	5.0	Alkalinity, Bicarb. as CaCO3 at pH 4.5	ND	5.0
Alkalinity, Carb. as CaCO3 at pH 8.3	ND	5.0	Alkalinity, Carb. as CaCO3 at pH 8.3	ND	5.0
Alkalinity, Hydrox. as CaCO3	ND	5.0	Alkalinity, Hydrox. as CaCO3	ND	5.0
Chloride	ND	3.0	Chloride	ND	3.0
Fluoride	ND	0.10	Fluoride	ND	0.10
pH (units)	4.8	--	pH (units)	4.3	--
Sulfate	ND	5.0	Sulfate	15.1	5.0
Specific Conductance at 25°C (umhos/cm)	5.6	1.0	Specific Conductance at 25°C (umhos/cm)	63.6	1.0

*ND--not detected.

Table C-5

Analysis of Water Samples From the Valley of Ten Thousand Smokes Under EPA Protocol, August 1991* (Continued)

River Lethe at Ash-Flow Site		
Parameter	Result (Mg/L)	Reporting Limit (Mg/L)
Antimony	ND	0.060
Arsenic	ND	0.0050
Barium	0.012	0.010
Beryllium	ND	0.0020
Boron	ND	0.10
Cadmium	ND	0.0050
Calcium	5.2	0.20
Cesium (133)	ND	0.0010
Chromium	ND	0.010
Copper	ND	0.020
Iron	1.1	0.10
Lead	ND	0.0050
Lithium	ND	0.050
Magnesium	1.1	0.20
Manganese	0.020	0.010
Mercury	ND	0.00020
Nickel	ND	0.040
Potassium	ND	5.0
Rubidium (85)	0.0016	0.0010
Selenium	ND	0.0050
Silica as SiO2	15.0	0.50
Silver	ND	0.010
Sodium	ND	5.0
Strontium	ND	0.050
Thorium (232)	ND	0.0010
Zinc	ND	0.020

ND--not detected.

Table C-5

Analysis of Water Samples From the Valley of Ten Thousand Smokes Under EPA Protocol, August 1991* (Concluded)

River Lethe at Ash-Flow Site		
Parameter	Result (Mg/L)	Reporting Limit (Mg/L)
Alkalinity, Total as CaCo3 at pH 4.5	6.3	5.0
Alkalinity, Bicarb. as CaCO3 at pH 4.5	6.3	5.0
Alkalinity, Carb. as CaCO3 at pH 8.3	ND	5.0
Alkalinity, Hydrox. as CaCO3	ND	5.0
Chloride	ND	3.0
Fluoride	0.10	0.10
pH (units)	6.5	--
Sulfate	9.6	5.0
Specific Conductance at 25°C (umhos/cm)	45.3	1.0

*ND--not detected.

REFERENCES FOR APPENDIX C

Keith, T. E. C. and S. Ingebritsen, 1991. "Advective Flux of Solutes and Heat from the Valley of Ten Thousand Smokes, Katmai National Park, Alaska," presented at the American Geophysical Union Fall Meeting, December 1991, San Francisco, CA.

Keith, T. E. C., V. M. Thompson, and R. A. Hutchinson, in preparation. "Chemistry of the Waters in the Valley of Ten Thousand Smokes, Alaska," *Journal of Volcanology and Geothermal Research.*

APPENDIX D

SPILL PREVENTION AND MITIGATION

APPENDIX D

SPILL PREVENTION AND MITIGATION

D.1. SPILL PREVENTION CONTROL AND COUNTERMEASURE PLAN

Guidelines suggested in information provided in 40 CFR 112, "Spill Prevention and Countermeasure Plan," are used in this section. This plan will be prepared for certification by an engineer. The quantities of fuel, described in Chapters 3.0 and 10.0, do not require a contingency plan for the State. However, the items contained in this Appendix and in Section 10.3 contain both elements of prevention and response.

Any changes in this plan between the 1992 writing date and the 1994 fielding date should be relatively minor and will not affect the overall scope (footprint) or magnitude of information provided in this plan. The drill crew will receive training in spill prevention, response, and mitigation.

A. <u>Name of Facility and Location</u>

Katmai Operational Sites--Operated by the Geoscience Research Office (GRDO) at Sandia National Laboratories (Agent) for the U.S. Department of Energy (Operator).

1. Dome Drill Site and Camp-Range 36 West, Township 22, Section 15.

2. Ash-Flow Drill Site-Range 36 West, Township 22, Section 8.

B. <u>Type of Facility</u>

The facilities are drill sites with diamond core rig and supporting elements. The dome drill site has a supporting camp. The facility is not permanent. It will be operated only during the 1994 and 1995 warm seasons (see Figure 8-3).

C. <u>Date of Initial Operation</u>

The date of initial operation will begin in Spring 1994.

D. <u>Location of Facility, Facility Layouts, and Storage of Fuel in Facility</u>

See Section A above and Figures 1-2, 1-3, 4-2, 4-3, and 4-4 of this document. Site layouts are shown in Figures 4-10 and 4-11. Waterline layouts are shown in Figure 8-1. (There will be some minimal amounts of fuel in each of the booster stations.) See Table 10-3 for estimated fuel storage for the facility.

E. Name and Address of Owner

U.S. Department of Energy
Albuquerque Field Office
P.O. Box 5400
Albuquerque, N.M. 87185-5400
Attn. Director
Kirtland Area Office

F. Designated GRDO Personnel Responsible for Oil Spill Prevention

Allan R. Sattler
Douglas A. Blankenship
Ronald D. Jacobson

G. Oil Spill History

N/A

H. Spill Prevention

Supplemental information on tanks and bladder is provided below. (For a more detailed discussion, see Chapters 10.0 and 14.0.)

1. Each tank will be UL 142 construction.

2. Outlet valves and power switches for pumps will have a locking capability.

3. Each tank will be equipped with a direct reading gage.

4. Venting capacity will be suitable for fill and withdrawal rates.

5. Dikes will be lined with an organic liner such as polyethylene with welded joints and with a minimum thickness of 30 mills. Because pumice is prevalent at the dome site, a felt-type geotextile material (a minimum of 75 mill thick), will be laid between the pumice comprising the berm and the polyethelene liner. A drain or a pump will be inside the berm at the lowest point to remove water. The volume is computed on the largest tank or bladder within either a 10% excess volume or with a freeboard of 1 ft. Allowance is made for additional vertical tank displacements below dike height.

I. Management Approval

The publication of the "Revised Katmai Operations Plan," including this Appendix, have been approved by the Project Supervisor, James C. Dunn, Department 6111, Sandia National Laboratories, as well as the U.S. Geological Survey in Anchorage.

D.2. SPILL PREVENTION AND MITIGATION

Spill Prevention

For safe handling of all sensitive materials and spill prevention, the operation will be reviewed by the project and an outside environmental contractor before commencement of drilling and coring. This review will evaluate all operations handling concerning the barge, the site-support area in King Salmon, and the drill sites. The use and disposal of all environmentally sensitive fluids will be reviewed. All stages of fluid use will be reviewed, including the operation and maintenance of equipment, record keeping, and emergency spill response.

A monitoring system will be erected to warn operating personnel of any unanticipated drop in a fuel tank level. Monitoring devices on the main monitoring system will display the drilling and hydrogen sulfide data. Tanks, lining of pits, and berm construction will (at a minimum) meet federal and state specifications.

If necessary, other sensitive materials such as the additives for liquid drilling fluid will be stored in a lined area. These storage areas will be inspected on each shift. Storage areas for additives of solid drilling fluid and dewatered drilling solids will also be inspected each shift. All areas containing critical materials will be well illuminated.

Visual inspections of all sensitive materials will be recorded at least once each 12-hour shift and will include examination of bladders, tanks, and other liquid containers and secondary (bermed) containers used for containment and integrity.

The drilling crews and all personnel working at the site will receive training in spill prevention, mitigation, and containment. The onsite training will include the following:

- transfer operations involving oil, drilling fluids. Personnel will be trained in the handling of hazardous material.

- operation and maintenance of equipment to prevent oil discharges and discharges of drilling fluids;

- familiarity with and training in the use and application of spill control equipment on hand, such as skimmers and boom pads; and

- knowledge of appropriate spill control regulations.

Periodic drill and support site inspections will be made by trained spill control personnel to ensure that the handling and storage of all sensitive fluids is proper, seepage of oil from machinery is minimal, records are in good order, and that the general operation is conducted in a manner that minimizes the chance of an accident.

Spill Response and Mitigation

If a spill occurs, the drilling project will follow the proper spill response and mitigation procedure determined by the severity of the spill. The GRDO Site Manager will coordinate remedial activities. A list of phone numbers of key personnel including permitting agencies (the National Park Service, U.S. Environmental Protection Agency, and State of Alaska Department of Environmental Conservation) and spill control personnel will be posted and contained in the site-specific Safe Operating Procedure. Depending on the location of the spill, remedial operations will be coordinated either from the dome drill site, the ash-flow drill site, or the site-support area in King Salmon. All three of these areas will have sufficient communication facilities to coordinate necessary activities.

A contingency contract with an Alaska firm will be established to effect remedial action in mitigating, containing, and cleaning up spills. Thus in the unlikely event of a severe spill, additional trained personnel and appropriate equipment could be dispatched to the problem area immediately. The contractor will provide trained manpower to combat spills and appropriate spill control equipment. If needed, this equipment would supplement spill control equipment either at the drill sites or equipment stored at the site-support facility in King Salmon.

For the containment of spills onsite, equipment that will be available to project personnel will consist of the following:

- Emergency tanks will be stored in King Salmon and brought in by helicopter to hold fuel if a transfer is necessary. Enough spare storage capability will be onsite for the largest tank of sensitive liquids.

- Oil-absorbent pads that are available commercially will be used on all fuel lines, connections, etc. Oil-absorbent pads will be placed generally where spills could occur from breaks in the line or leaks, such as under machinery, pumps, etc. A large number of all types of absorbent pads and materials that are sufficient to meet contingencies will be stored in reserve at the site and at the site-support facility in King Salmon. Approximately 40 empty barrels approved by the U.S. Department of Transportation will be stored at King Salmon to transport waste from a spill.

- An industrial rug or other suitable rug will be used to absorb fuel and drilling fluid in critical areas, including areas around mixing tanks and places where small spills of drilling fluid could occur.

- Appropriate absorbent booms will be kept in the site support area in King Salmon. Materials in storage will include adequate supplies of river booms for strong, moderate, or light current, and sheltered water booms that would be sufficient for a first response to any fuel spills.

- A skimmer will be used that would be suitable for a first response to a spill on water. For example, if a helicopter goes down on

water or if a portion of a helicopter load is lost, a skimmer would be used to contain the spill, if necessary. Helicopters will be used to transport fuel to and from project operations. These helicopters can transport between 150 and 3,000 gal of fuel. Their fuel tank capacities range from 300 to 1,000 gal. The terrain around the site is barren ash. The terrain closer to King Samon is lush with many bodies of water of all sizes. Because of these considerations, it is felt that King Salmon is best suited for storage of much of the response material.

The project group will respond to all spills immediately. In general, the sequence of events in response to a spill will be the following:

- proceed to the spill site and assess the nature of the incident,
- determine the nature of appropriate action, and
- implement appropriate response.

The appropriate authorities should be notified as soon as practicable during the above sequence. In general, a response to a spill of sensitive fluids will include the following:

- caring for any injured personnel that may have occurred as a result of the accident precipitating the spill;
- spill containment, including the spreading of sorbents and the formation of temporary dikes or spreading an appropriate array of sorbent boom pads on water;
- appropriate source removal with proper removal of source contents;
- cleanup and adequate decontamination;
- collecting wastes and resanding residues and placing them in proper containers; and
- proper waste disposal.

The following classification of spills by severity has been provided so that responses can be tailored to the severity or volume of the spill.

Minor Onsite Spills and Leaks of Fuel or Contaminants Less Than 10 Gal

These will be controlled by site personnel. The conduct of normal operations will not be disrupted if a rapid, effective response can be mounted.

Spills or Leaks of Fuels and Contaminants Greater Than 10 Gal

Onsite Spill — If possible, containment and cleanup will be conducted by site personnel; if not, contract spill technicians will be brought in to manage the spill. Operations will be curtailed to a minimum level until it is environmentally safe to resume normal operations. During curtailment of the operations, the onsite crew and a spill technician (if necessary) will clean up the spill and take necessary remedial action. (It may be necessary to maintain circulation in the well if a high temperature regime is encountered.)

Offsite Spill — Any spill away from the site no matter how small will be regarded as a spill of at least intermediate severity. The spill will be assessed by the project personnel and the resident Park Ranger. If possible, the project personnel from the drill site or from the project support area in King Salmon will make the first response using helicopter transport. Minor spills will be cleaned up immediately. If practical, the entire cleanup will be made by project personnel. The firm specializing in spill cleanup under contract will be notified immediately of any offsite spill. At least one technician will arrive as soon as possible to assist with and inspect the clean-up operation. Conformance to environmental or operational considerations may dictate the assembly of a larger clean-up crew appropriate to the magnitude of the accident.

Handling and Removal of Spilled Material

If liquid spills into the lined berm, it will be pumped back into another storage tank or barrel and used or held for transport. Then it will be removed out of the park by helicopter for proper disposal at an approved site. For proper disposal, fluids skimmed off water will be stored in portable tanks for transport out of the park. Oil-soaked debris will be containerized for disposal.